rt No. UMTA-MA-06-0025-77-16

DEVELOPMENT OF ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

L.R. Damskey
G.T. Gin

Bechtel Incorporated
50 Beale Street
San Francisco CA 94105

DECEMBER 1977
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Office of Rail Technology
Washington DC 20590

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0025-77-16		

4. Title and Subtitle	5. Report Date
DEVELOPMENT OF ECONOMIC FACTORS IN TUNNEL CONSTRUCTION	December 1977
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
L. R. Damskey and G. T. Gin	DOT-TSC-UMTA-77-37
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Bechtel Incorporated * 50 Beale Street San Francisco CA 94105	UM704/R8723
	11. Contract or Grant No.
	DOT-TSC-1104
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Urban Mass Transportation Administration Office of Technology Development and Deployment Office of Rail Technology, Washington DC 20590	Final Report January 1976-September 1977
	14. Sponsoring Agency Code

15. Supplementary Notes

*Under Contract to: U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

16. Abstract

The escalating cost of underground construction of urban transportation systems has made transit planning, and especially construction cost estimating, difficult. A statistical study of the factors which influence tunnel construction costs was made to determine the magnitude of the major factors involved in construction cost. Tunnel construction data on cost and resources expended was collected and used to develop relations between construction rate of advance (ROA) and the important physical variables. The data is also used in an analysis of the cost impact of institutional factors such as:

availability and analysis of geologic conditions
flexibility and quality of engineering specifications
conditions for obtaining right-of-way and construction and entry permits
potential contractor liability
labor agreements .

Utilization of the study results are expected to better the accuracy of cost estimating procedures for future tunnel construction.

17. Key Words	18. Distribution Statement
Tunneling (Rate of Advance) Planning and Estimating	DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	204	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

A study of the cost of construction of underground, rapid transit tunnels in soft ground was instituted under U.S. Department of Transportation contract DOT-TSC-1104. The scope of construction work to be considered was that:

- Between existing shafts or stations and

- Completion up to and including the pouring of all finished concrete

The study was completed through an estimation of tunneling hours and downtime hours to give an expected value, and distribution about that value, of the total shift hours involved from start to breakthrough of the tunnel. Additionally, some subjective factors influencing contingency and profit are presented.

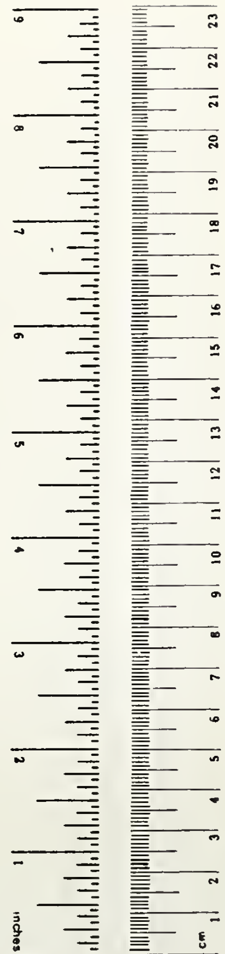
The study was sponsored by the Office of Rail Technology of the Urban Mass Transportation Administration, the Transportation Systems Center under the direction of Mr. Andrew Sluz, the Technical Monitor. Mr. Joseph Keating, of Keating Associates, was the outside consultant and provided data for the effect of institutional factors.

Data from the Chicago tunnels were provided with the assistance of Messrs. R.I. Leland and S.J. Sulinski of the Metropolitan Sanitary District of Greater Chicago. Ing. Manuel Salvocho, of Ingenieros Civiles Asociados, S.A., kindly provided information on Mexico City tunnels. Other data were gathered and analyzed by Bechtel personnel; P.L. Shank (WMATA), N.N. Munnerlyn and F.E. Velez (BART) inspected hundreds of log sheets. Analysis of the data was performed principally by L.R. Damskey with the able assistance of V.J. Miller.

METRIC CONVERSION FACTORS

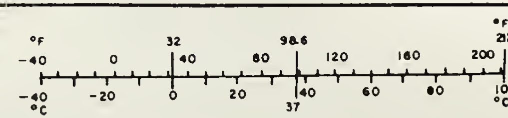
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



CONTENTS

ILLUSTRATIONS

TABLES

1. SUMMARY

Twenty-two tunnels from the San Francisco Bay Area Rapid Transit District (BART), the Chicago Metropolitan Sanitary District, and the Washington DC, Metropolitan Area Transit Authority (WMATA) have been analyzed to determine what factors influence the Rate of Advance (RoA) through the ground. The major effect is the increase in productivity achieved through the effect of the Learning Curve. Other effects, due to soil and equipment types, are multipliers to the basic equation.

Downtime for the various pieces of tunneling and muck-removal equipment are random events that are difficult to forecast, although trends were found and estimates determined.

An important aspect of the study was to quantify the variability of the rate of advance and down time calculations. The estimator does the same in a more subjective manner - each referring to his personal source of information to decide the effects of expected soils and equipment on the rate of progress through the ground. The results of our study in quantification of these variables are a step in the direction of understanding some of the tunneling cause and effect relations and giving the causes a numerical value. Quantification of these variables should reduce the size of the contingency applied by the bidding contractors to more meaningful terms of risk.

Data on the mining progress through the ground were of a poor quality. In order to provide better data for analysis from future tunnels, recommendations have been suggested for the tunnel (Ring & Face) log. At best, the recommended data acquisition will quantify the future tunneling rates. At worst, the analyst will be given a better subjective view of what occurred during tunneling.

2. SELECTION OF COST ESTIMATING TECHNIQUES

2.1 REVIEW OF SYSTEMS ANALYSIS METHODS BASED ON COST ESTIMATES

Rapid transit tunneling is not an often repeated construction effort in which costs can be scaled to the next tunnel. Nor can a few inflation indexes be used to go from one time frame to a future period. And lastly, no two tunnels will have the same ground conditions and equipment uses. No two tunnels are the same!

Because of these differences, it seemed appropriate for the analysis to examine the tunneling systems and not their costs. Barring new technologies, some combination of personnel, equipment, and soils, taken from many experiences of the past, will be brought together for tunnels to be built in the future. Our effort, therefore, was to determine the individual contributions of each of the components. And with that knowledge, we can estimate the resources to be used for a specific future tunnel and price out the resources at their going market price at the time the tunnel is to be built. Escalation factors can be more accurately estimated on a component by component basis at that time.

2.2 SELECTION OF OPTIMUM COST ESTIMATING AND ANALYZING TECHNIQUES

The main components of a tunnel's construction are manhours, equipment depreciation and maintenance, and bulk materials.

- Bulk materials — concrete, rebar, grout materials — are largely a linear function of the tunnel's length.

- Equipment depreciation and maintenance should be available from historical records as well as from published data.

- Manhours represents the crew size multiplied by the shift hours from beginning to end. (The question is how many hours will be involved? Shift hours are composed of tunneling hours plus equipment shutdown hours.)

Estimates of tunneling hours based on linear feet per hour have not resulted in an adequate estimate. The main effort should be a systems analysis of the rate of advance (RoA) through the ground.

2.2.1 The Soils Estimate

A probability analysis relating core analyses to what was found during the tunneling should be conducted. Conditional probabilities, P (Soil B | Soil A), are based on the presence of one type to predict another. And Baysian probabilities can be used to increase the likelihood of predicting probable soil characteristics with the inclusion of additional data (new core samples).

All this can be displayed by a probability tree [1,2] to determine the soils most likely to be encountered at various distances through the ground.

2.2.2 Tunneling Equipment

Several different methods of face excavation are available: the one-direction rotating cutting wheel, the cutting wheel capable of reversal, the oscillating wheel (reputed to be no longer available), the digger arm (similar to a backhoe), and manual digging. Depending on how many types of excavating processes were to be found, Discriminate Analysis could be used to find which excavation process was likely to be used with which types of soil, tunnel length, and other tunnel parameters.

2.2.3 Mucking Equipment

Discriminate analysis could also be used to determine which muck transport system fits the other tunnel characteristics best.

2.2.4 Crew Size

Crew size and the various categories of skilled and unskilled crafts are expected to be a function of the equipment used. This can be found with a simple matrix having rows and columns of excavation and types of mucking equipment.

2.2.5 Rate of Advance (RoA)

Using the weekly advance rates as the dependent variable, regression analysis can be used to relate it with the many soil characteristics, equipment used, and primary liner types.

2.2.6 Downtime

Reliability theory, together with regression analysis, can be used to estimate the amount of time the equipment would be down and unavailable for tunneling operations. Maintenance costs are, of course, related to down time.

3. QUANTIFICATION OF FACTORS WHICH INFLUENCE CONSTRUCTION COSTS

3.1 PHYSICAL CHARACTERISTICS

The set of physical variables decided on, after reviewing several sets of tunneling data, were:

Tunnel Rate - ft/wk	Water Running in Tunnel - 1 → 2
Cumulative Feet of Tunnel to Date	Hp to Cutter/Digger
Tunneling Hours in Week	Total Jacking Potential of Shield - tons
Shield Down Time - hr/wk	OD of Shield - ft
Excav Equip Down Time - hr/wk	Shield + Rotating Wheel - 1/2
Conveyor Down Time - hr/wk	Shield + Oscillating Arms - 1/2
Muck Transport Down Time - hr/wk	Shield + Digger Arm - 1/2
Misc Down Time - hr/wk	Shield + Manual Digging 1/2
Admin Down Time - hr/wk	Mucking Equip: Conv Belt + Train - 1/2
Total Shift Time - hr/wk	Mucking Equip: Conv Belt + Truck - 1/2
Silt & Clay - 1 → 2	Mucking Equip: Rubber Tired Truck 1/2
Clay & Sand - 1 → 2	Grnd: Non-Cohesive - 1 → 2
Sand & Gravel - 1 → 2	Grnd: Running - 1 → 2
Cobbles & Boulders - 1 → 2	Lining: Ribs & Lagging - 1/2
Cemented - 1 → 2	Lining: Conc Pipe Jacked into Place - 1/2
Peat & Trash - 1 → 2	Last Week of Tunneling = 1/2
Cohesive - 1 → 2	
Tunnel Pressure - psig	

1 → 2: Varies between values of 1 and 2
1/2: A no/yes variable with a value of 1 or 2, usually

Based on the tunnels investigated, we believe these data items are adequate to describe the tunneling system and its RoA.

During the last six tunnels investigated, the soil was predominately sand with clay and with poor standup time. Some breasting was required, and consideration was given to adding this as another parameter. It was dropped because breasting was not the major cause of slowdown (even though

breasting did slow the RoA). The major cause was adequately described by the basic soil variables of Sand and Clay and Running Ground.

The quantification of the physical factors is discussed in Section 5 and 6, Analysis of Data and Predicting Equations.

3.2 INSTITUTIONAL EFFECTS

Institutional effects are generally subjective variables that enter into the contingency. To a large degree they are subjective because they are not directly measureable. The factors decided upon for this study are:

(1) Schedule/Time

Traditionally, bar charts have been used for scheduling; but these charts only show the time for beginning and end of activities. A network (CPM/PERT) chart shows the interrelation of activities which must be completed before another activity can start. Without this type of analysis, proper planning cannot occur; time overruns on subsequent activities are not likely to be understood.

(2) Direct Costs - Owner Acquisition

- Land and Rights-of-Way. Generally the owner can more expeditiously accomplish these activities (including the right of eminent domain). Entry to buildings and their preexcavation underpinning are also included.

- Materials. For items of equipment that will span more than one subcontract, procurement costs may be reduced, including the cost of financing monies.

- Insurance. The same rules would pertain to each subcontractor. The consistency of the policy and its jobwide scope should reduce the premium costs.

- Building Permits. This would not seem to be as cost sensitive to owner participation. Although

the reduction of personnel involved (owner and city agents) might expedite permit acquisitions, each must be processed individually. Negligible effect.

(3) Labor Productivity

Total job agreements are preferential so that each craft is responsible and is treated the same on each subcontract. It would appear to be more expeditious if the Owner negotiated the agreement and had it in hand by the time the bids were awarded.

It is expected that there are differences in productivity. Factors were investigated. Our findings indicate a wide range of subjectivity with little or no quantification of the indices.

The demand on a given labor market is believed to have an effect: e.g., if the building economy is booming in a specific area, additional demands on the local labor market are likely to be met with personnel of marginal productivity.

Compressed air work is subject to local labor negotiations. During the BART construction contracts 1M0031/1S0022, the generalized maximum hours of work were restricted by the air pressure to:

$$\text{Max hr} = 8.0-0.134(\text{psig}) \qquad (3.1)$$

Labor negotiations resulted in an annual pay rate increase. For the three-year period, 1968 to 1971, and including the annual inflation index, the hourly wage rate is described by:

$$\$/\text{Hr} = \left[1.1036\ (\text{Max psig})^{-0.0133}\right]^{n} * \left[\frac{1}{0.1715-0.0032\ (\text{Max psig})}\right] .$$

where: n = years since contract was first in effect (3.2)

The above applied to all union rates while under pressure. Foremen received $4/shift in addition.

4. DATA DESCRIPTION

4.1 SOURCES. The data were found in the following forms:

1. BART: 1M0031-MR,ML; 1R0053-RR,RL.

   The excavation and downtime data had been summarized into weekly increments. Soil characteristics were taken from a soil profile and written verbal descriptions. Other data were in the tunnel report summaries.

2. BART: 1S0011-TR,TL,SR,SL; 1S0051A-SR,SL.

   All data were obtained from rough logs: the ring erection log with two rings/page, the foreman's log, and a weekly advance summary.

3. Chicago Metropolitan Sanitary District: Upper Salt Creek tunnels 1, 2, and 3.

   All data were taken from weekly data summaries, soil profiles, and written records of equipment used. In one case, it was necessary to contact the shield fabricator for data.

4. WMATA: 1F0012-FIB North Outbound, North Inbound, South Outbound, South Inbound; 1F0021-F2A Outbound, Inbound Branch Route Outbound, Branch Route Inbound; 1D0091-D9.

   All data were taken from the ring report logs (one page/ring), soil profiles, written rough logs, and oral communication with personnel involved in the tunnel excavations.

5. Mexico City Deep Sewer.

   The data were received too late for study and analysis. The text is in Spanish and is appended (Appendix B) as a potential source of information. The tunnel characteristics were different enough to have been useful in the analysis.

Copies of the original data are found in Appendix A-1,2.

4.2 SOILS

Soils engineering suggested classifications other than those ultimately used. The difference lay in that the descriptions used by the face crew foreman were not those of a soils engineer, and the face crew foreman, for all his lack of exact scientific expertise, was in the hole and making a continuous log of the face conditions as he saw them. The categories finally used were:

- Silt and Clay
- Clay and Sand
- Sand and Gravel
- Cobbles and Boulders
- Peat and Trash
- Cemented
- Cohesive
- Running .

For each soil category, a value between 1 and 2 (0 to 100%) was to be assigned so as to describe the average face composition. The logged data did not permit the inclusive description, and in many cases the composition does not add to 100 percent. Fortunately, the transitory changes did not appear to have major effects on the RoA.

Running water affected the RoA whether the water was perched or from an unlowered water table. The quantity of flowing water was not metered. Our quantification became:

- 1.0 Dry
- 1.25 Moist
- 1.50 Wet
- 1.75 Running and impeding operations
- 2.0 Flooding and stopping operations .

4.3 PRIMARY LINING

All but one tunnel used either steel segmented rings or ribs and lagging. The one exception was in Chicago's Upper Salt Creek No. 2 sewer intercept, where a 9.28-foot-diameter shield was used. The concrete lining, being both primary and finished, was lowered in segments through the nearest following shaft and jacked into place over a slip bed of wet bentonite. Later the bentonite was replaced with a cement grout.

4.4 MINING OPERATIONS

For each tunnel analyzed from the basic logged data, the time for the shove, the ring erection, and what is here called "dead time," was obtained. From these data, a pseudo RoA equation was developed for each tunnel involving the intercept and learning-curve exponent in the form of equation (5-1). Time and resources did not allow further analysis. It is suggested that further study of the data may disclose information that would permit the tunneling contractor to increase his efficiency for these operations.

4.5 DATA PROCESSING

In both the RoA and downtime estimating equations, the logic suggested that cumulative feet would be the dominant independent variable (in the latter equation, Σ ft represents time, most frequently found in reliability analyses), and all other independents would act as multipliers representing the perturbations around the relation between the dependent and independent variables. To accomplish this, the multiplier must have a value of 1 when the parameter in question has no effect; a "1" or a "2" was used in no/yes statements and a range of 1 to 2 was used to denote a characteristic that varied fractionally between 0 and 1.

4.6 GROUT

Only the BART 1S0011 TL/SL tunnel's grouting data were analyzed. Both pea gravel and cement grouts were used in the ratio of 1.54:1. The total grout consumption was 4.1 percent greater than the theoretical void left by the shield.

Although of minor cost, it may be possible to relate the consumption of grout to the soil types.

5. ANALYSIS OF DATA

5.1 BACKGROUND

Tunneling, taken in its entirety, comprises so many diverse activities that it soon became obvious that it would be necessary to divide it into subtasks that were basically homogeneous in order to model each as a unit operation. The resulting concept is shown in Figure 5-1.

The activities within the dotted line framework are concerned only with nonmonetary resources.

- The tunnel length defines the quantities of bulk materials to be used. It also influences the choice of tunneling equipment and influences the RoA.
- Soil characteristics and primary liner types both influence the tunnel equipment choice and affect the rate of advance.
- Tunnel equipment sets the crew size, influences the contractor's capital costs, and affects the RoA.
- The above then set the RoA and have a large effect on equipment reliability.
- From the RoA, the tunneling hours are estimated.
- Equipment reliability estimates the downtime hours.
- The combination of crew size, tunneling, and down hours provides the estimate of nonexempt crew manhours.
- Current costs are then applied to estimate the tunneling cost without contingencies and profit.
- Institutional factors (identified contingencies), unidentified contingencies, and profit are applied to reach a total cost.

- Throughout the calculations, an error of estimate is carried. The various costs (the result of the average values for all the above) and their variations are combined in a risk model (Monte Carlo) simulation to obtain a range of total costs and the probability of the occurrence of each.

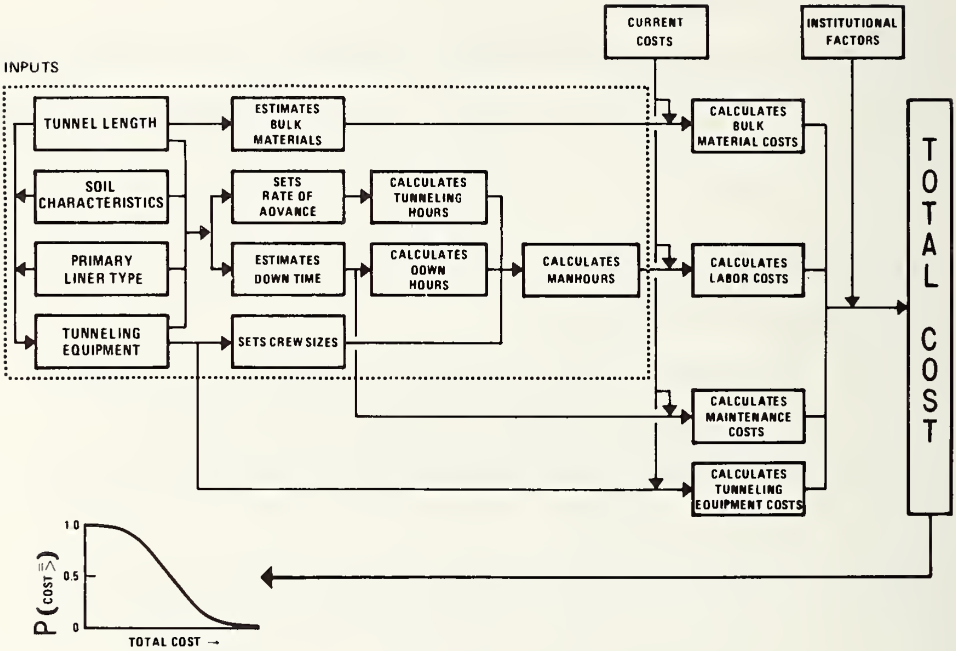


Figure 5-1. Economic Factors in Tunnel Construction

5.2 LEARNING CURVE

Literature research on Rate of Advance analysis yielded little in the way of mathematical analysis. Several authors mentioned that the RoA increased as the crews learned to work together and equipment deficiencies were eliminated.(3) One author(4) used the term "Learning Curve." An analytical approach is given by Pietrzak and McJunkin(5) based on hard-rock tunneling. Although these authors do not provide details of their model's logic, it does appear that there may be similarities between their model and the work being reported on here.

The concept of a learning curve where subsequent repetitive work is achieved at a higher rate of productivity is certainly not new.[6] The airplane frame industry found that with their mixture of manual and machine work, an 80-percent curve, on the average, defined their increase in productivity. That is, each time the number of airframes produced was doubled, the last unit required only 80 percent as much time as the reference unit. In the case of tunneling, using the average learning curve exponent found for all the tunnels studied, 82.3 percent, and an initial rate of 4.0 hours/foot, the following rates might be expected.

Cumulative Feet of Tunnel	Hours/foot	Feet/hour (RoA)
1	4	0.25
2	3.29(4x0.823)	0.30
4	2.71(3.29x0.823)	0.37
.	.	.
.	.	.
128	1.02(1.243x0.823)	0.98
.	.	.
.	.	.
1024	0.57(0.693x0.823)	1.75
2048	0.47(0.57x0.823)	2.13
4096	0.39(0.47x0.823)	2.59

In general, industry has found that the degree of learning depends on the mixture of men and machines used. Figure 5-2 describes the change in learning curve, as reported by Hirschmann,[7] with the percentage of manual effort used in the specific task.

It seemed obvious that the learning curve should apply to the repetitive tasks of the shove and primary ring erection. Theoretically, the learning curve should be a continuous negative-sloping curve. In actual practice, interruptions to the work (equipment failures, planned shutdowns, etc) as well as modifications to the tasks (different soils, substitution of new equipment) occur to change the position of the curve.

A new soil might displace the curve. New equipment might merely involve an upward perturbation and then a rapid increase in productivity to again reach the former curve position.

In general, what might have been expected from a theoretical "learning curve" approach to the analysis is what was found for the RoA in soft-ground tunneling.

An example of the persistence of the Learning Curve was found in the BART RR/RL tunnels. Upon completion of the RR tunnel, the shield was immediately moved to the RL tunnel and tunneling continued. Except for an initial perturbation to the RoA, the advance rate quickly fell into line with the rate being achieved at the completion of the RR tunnel.

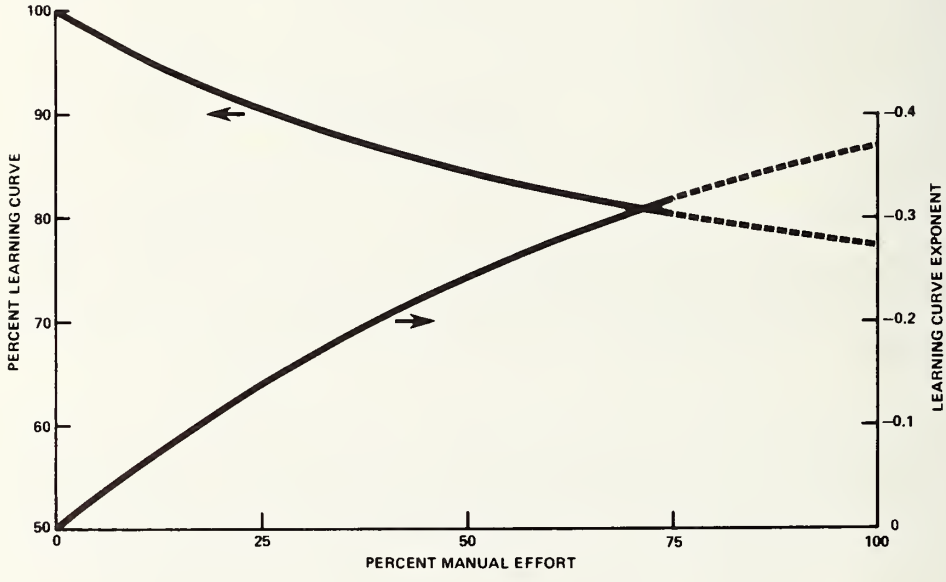


Figure 5-2. Relation Between the Percentage Mix of Manual and Machine Effort, Percent Learning Curve, and Learning Curve Exponent

5.3 PRELIMINARY ANALYSIS

In order to explore the learning-curve concept, raw data for several tunnels were plotted; Log (hr/ft) vs Log (cumulative ft), Figure 5-3. The learning-curve function is of the form

$$hr/ft = I(\Sigma\ ft)^{E} \tag{5.1}$$

where: Σ ft = cumulative feet

I = hr/ft for the first foot of excavation

E = the learning-curve exponent

$$Hr/ft \equiv (RoA)^{-1}$$

and: $$\text{Percent learning curve} = 100 \exp\ (E * \text{Ln } 2) \tag{5.2}$$

Data sets for the first three tunnels had been summarized into weekly units of data; therefore, all subsequent data accumulations were kept in a weekly format. The dependent variable (hr/ft) is the weekly tunneling hours, exclusive of any down time, divided by the feet of advance accomplished during the week.

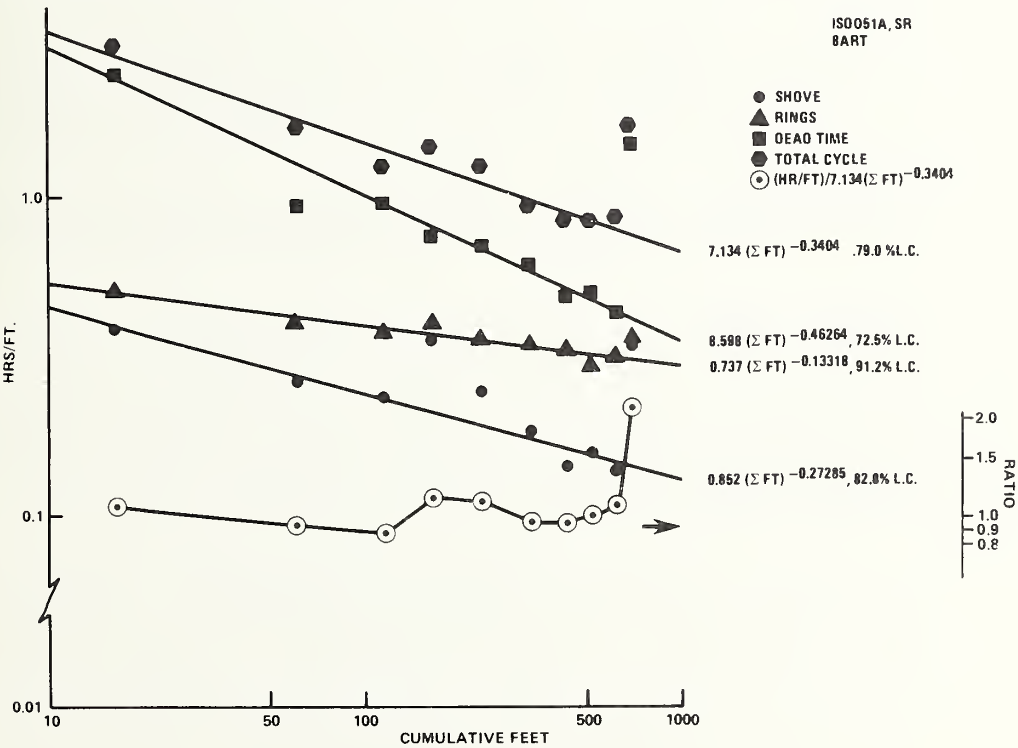


Figure 5-3. Tunneling Rate of Advance vs Cumulative Tunnel Length

The independent variable (Σ ft), in order to be compatible with the weekly average characteristics of the dependent variable, is calculated as the cumulative sum through the previous week's excavations plus half of the current week's distance.

The data can then be regressed to determine the values of I and E. The resultant equation can then be considered to be a rate equation

$$\frac{d\,(hr)}{d\,(ft)} = I\,(\Sigma\ ft)^{E} \tag{5.3}$$

and can be integrated between distances n and n + m.

$$d\,(hr) = I\int_{n}^{n+m} (\Sigma\ ft)^{E}\ d\,(ft) \tag{5.4}$$

For reasons that will be discussed later, valid results will not be obtained by integration between zero and the total number of feet in the tunnel; integration should be in parts to conform to the types of soils and other perturbations expected to be encountered during the excavation.

By calculating the number of hours required to excavate the tunnel and given the crew size, the number of tunneling manhours is estimated.

However, equipment does fail. And when the equipment is down for repair (or, for that matter, whenever there is a shutdown), the crew is usually on standby and must be paid. Therefore, it is necessary to estimate the downtime that may be encountered. Reliability theory has found that equipment generally responds as shown in Figure 5-4.

In developing a failure-rate function, the dependent variable was defined as hrs down/ft and the major independent variable as cumulative feet; both specified in weekly terms as before. A predicting equation to develop the number of downtime hours during the tunnel excavation will permit the estimation of crew manhours idled. The sum of the tunneling and downtime hours is an estimate of the non-exempt payroll and the time duration of the tunneling.

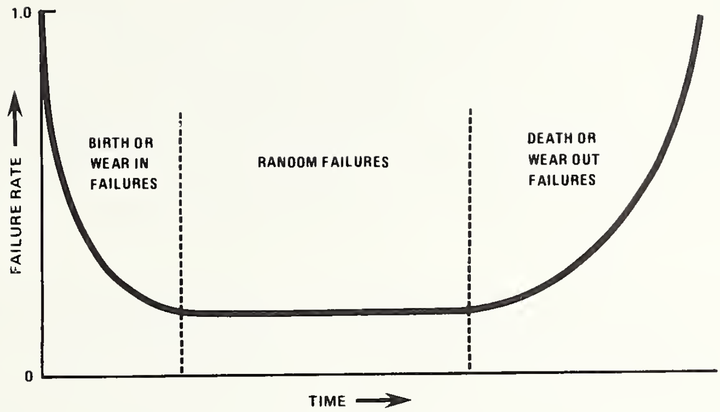


Figure 5-4. Typical Equipment Failure Rate Curve with Time

It is of primary importance to note that the Rate of Advance is not assumed (as is normally done). It is calculated, based on the conditions expected to be encountered. Among those conditions are the soil characteristics (either from a decision-tree estimate or a core-boring profile) and the equipment to be utilized.

Figure 5-1 shows the cost calculation logic. It is expected that, once the soils and tunnel length are specified, the tunneling and mucking machinery ranges are considerably reduced. And when the machinery is decided upon, barring labor union restraints, the crew size is determined. On the basis of the foregoing evolved concepts, some details of the analytical work will now be discussed.

5.4 METHOD OF ANALYSIS

Regression analysis was used to determine the effects of the so-called "independent" variables on the dependent variable, hr/ft. Independent variables should be independent from each other but, in commercial practice, a high degree of interdependence is usually found among these factors; i.e., a high degree of statistical randomness among the variables might well indicate a poorly managed project.

In fact, the lack of independence, when analyzing the individual tunnel data, resulted in the derivation of some learning-curve exponents that were considered to be impossible. The method of getting around this problem was to plot each tunnel's hr/ft vs Σ ft on log-log paper. The obvious outliers could then be eliminated. Outliers, in this sense, means those data points which are displaced from the negatively sloping line due to some other variable effects, such as a change in soils, a series of mechanical breakdowns, etc. The remaining data sets were then related, using only a desk calculator, to solve for the I and E of each tunnel.

The next step in the analysis was to find the effects of the remaining variables. The logic suggested that the effects of the other variables would be as multipliers; therefore, the regression used the logarithms of the variables.

$$\mathrm{Ln}\left(\frac{(\mathrm{hr/ft})}{I(\Sigma\ \mathrm{ft})^{E}}\right) = f(\mathrm{Ln}\,X_1, \mathrm{Ln}\,X_2, \text{---}, \mathrm{Ln}\,X_n) \qquad (5.5)$$

The above reasoning was tried on several tunnels. The following set of figures demonstrates an example from one of the WMATA tunnels. Figure 5-5 is the plot of hr/ft vs Σft. Figure 5-6 is a logarithmic

plot of the same data with the assumed outliers circled. Figure 5-7 is a transformation of the dependent variable to the form used in equation (5.5) vs Σft; the learning-curve effect on productivity has been removed. The data have now been normalized and all data sets are scattered about a horizontal axis having a value of 1.0. Figure 5-8 is a plot of the unexplained residual (reported-predicted)* vs Σft after regressing in the form of equation (5.5).

The scale of the ordinate is the same as that of Figure 5-7. It can be seen, in comparing Figures 5-7 and 5-8, that the variance from the horizontal line is greatly reduced in the latter. It appears that regression analysis can develop a mathematical model that will satisfactorily estimate a tunneling Rate of Advance.

To determine how closely the tunneling hours can be duplicated, a different set of tunnel data were regressed to estimate the weekly Rate of Advance. The corrections due to soils, equipment failures, etc., are fractional multipliers whose effects are different depending upon the numerical value of hr/ft.

Two methods were used in the calculation. One was to integrate the derived equation between the weekly stations. The other was to multiply hr/ft by the weekly advance. The results are shown in Figure 5-9.

*Note that the word "reported" is used rather than the usual word "actual" in calculating the unexplained residual. In general, the reported data were extremely doubtful in character. In one case, the soil changed from sand and clay to sandy clay and back again as the shifts changed. And sometimes, damp, wet, or moist sand was used interchangeably. Throughout our investigation into the raw logged data, it was obvious that little or no attention had been given to consistent observation and logging of data. And certainly no thought had ever been given to the possible future use of the data in a quantified analysis.

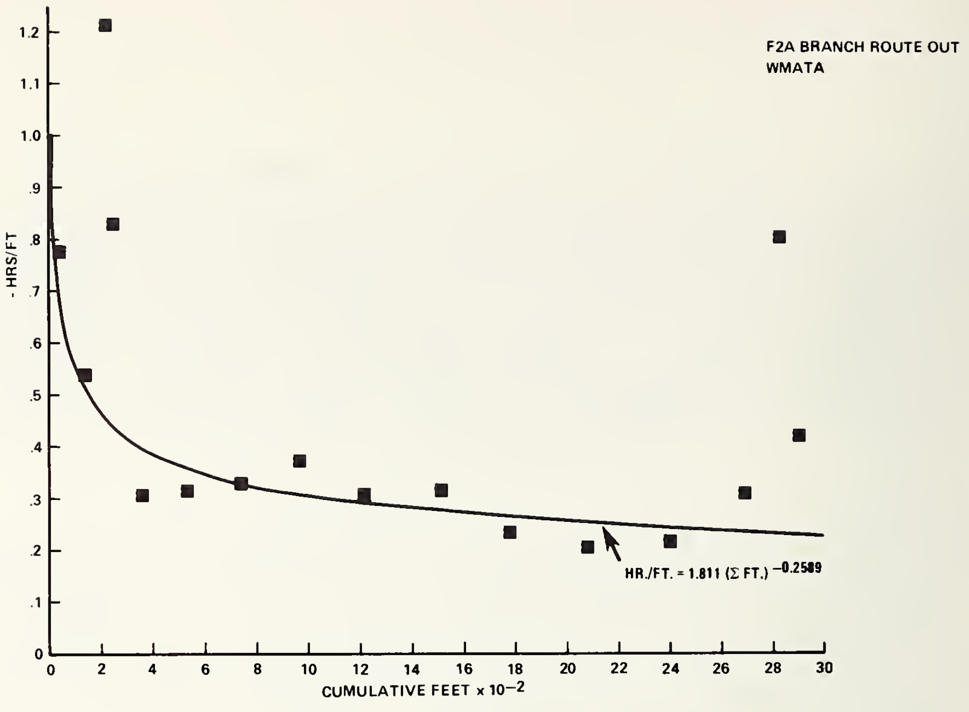


Figure 5-5. Rate of Advance vs Cumulative Tunnel Length

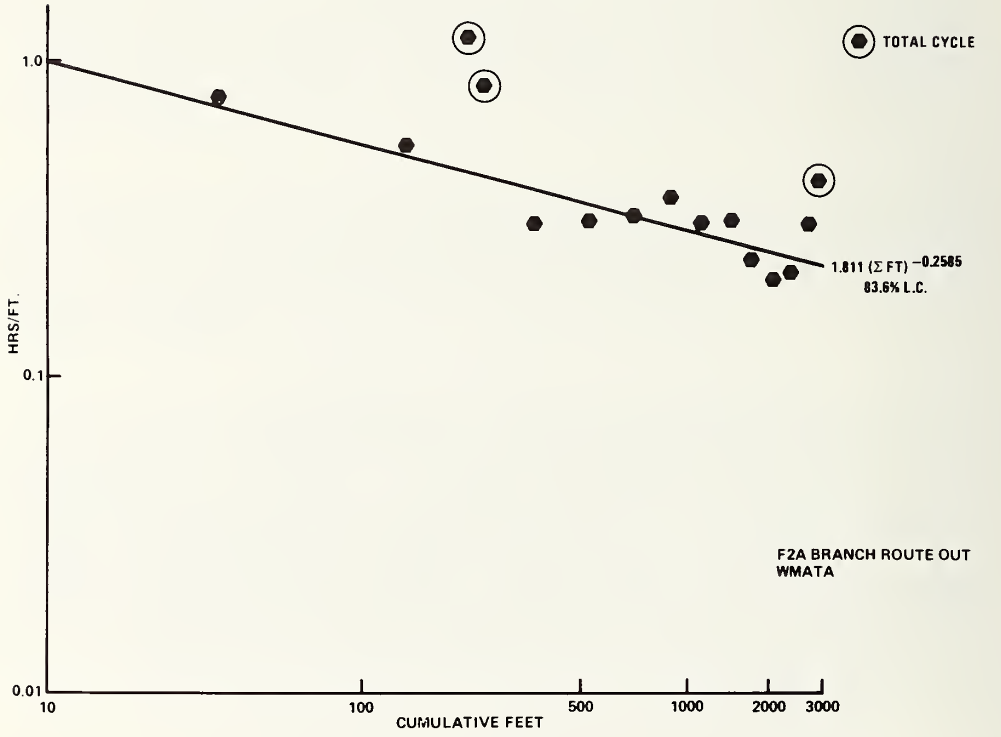


Figure 5-6. Tunneling Rate of Advance

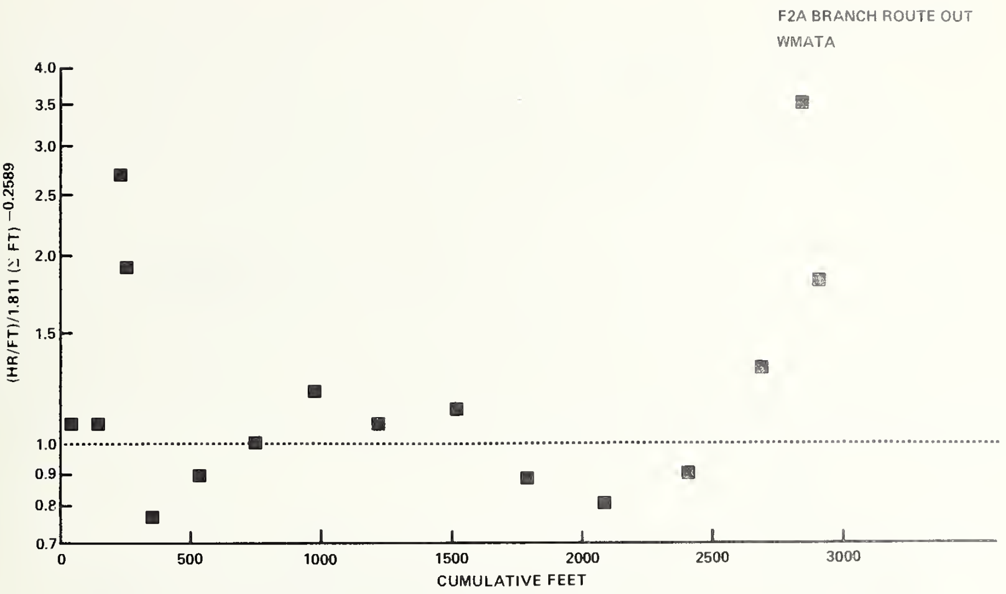


Figure 5-7. Tunnel Length; Unexplained Variations in Rate of Advance

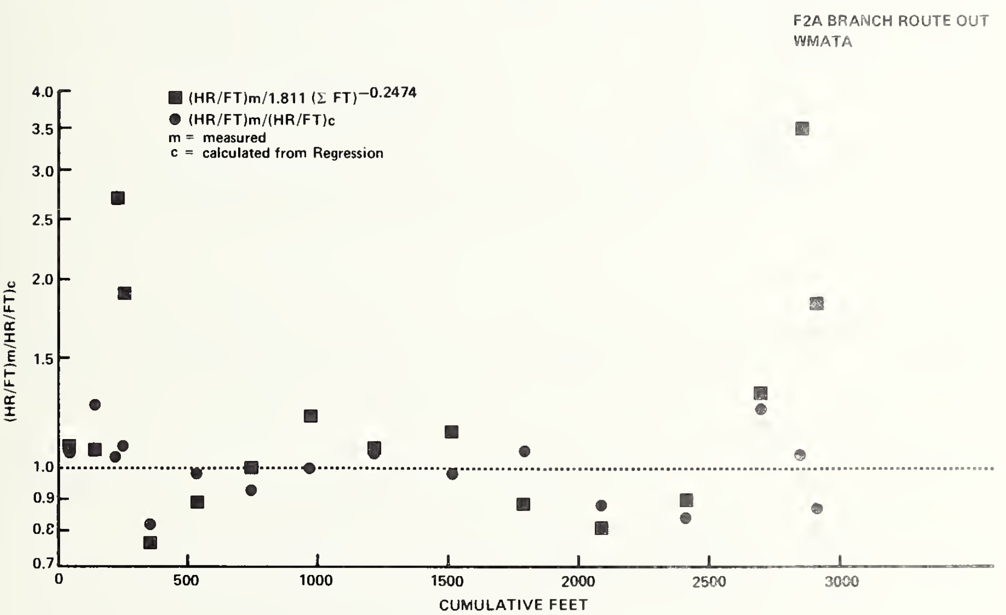


Figure 5-8. Reduction in Variance due to Equipment, Soil, and Length of Work-week Variables

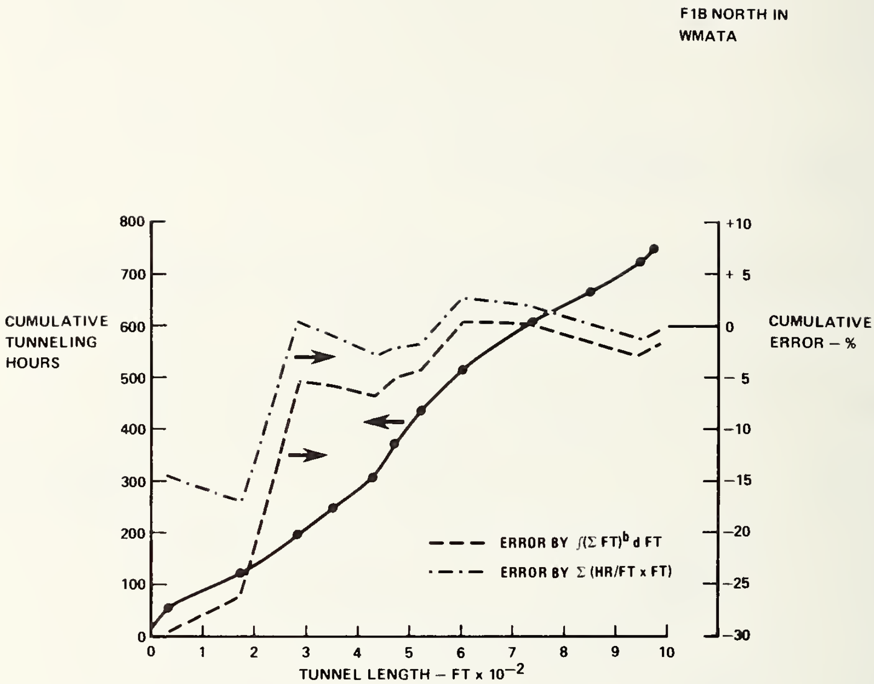


Figure 5-9. Comparison of Calculated and Reported Cumulative Tunneling Hours vs Tunnel Length

In the integration case, the error was 2.2 percent — 749.4 hours reported vs 766.0 hours calculated. In the summation case, the error was 0.7 percent — 749.4 hours reported vs 754.6 hours calculated. Again, the logic of the model development appeared to satisfactorily duplicate the reported tunneling hours.

5.4.1 Cross Tunnel Derivations

RoA equations were derived for several individual tunnels in order to investigate potential problems which might occur when all the data were combined. For instance, there were statistical outlier data points in the individual tunnel data for which there were no explanatory variables.

- An error could have occurred in the dependent variable, hr/ft. The lineal tunneling distance was probably correct, because both the starting and finishing stations were always compared with the number of rings erected. The error was most likely in the tunneling hours; i.e., shutdowns had occurred and were not reported or were incorrectly reported. This would result in too great a value for hr/ft in this data set.

- Errors in the independent variable could (and did) occur because of incomplete tunneling data logs; e.g., the soil characteristics changed and were not reported.

These outlier data were generally removed from the regression data before combining all data sets.

The combination of all the tunnel excavation data, with all the soil and equipment variations, permitted the derivation of an RoA equation that could not be derived with the limited variations in soil characteristics and single equipment sets found in individual tunnels. Additionally, the RoA equation used the intercepts and learning-curve exponents derived from the individual tunnel data.

Both the intercepts and learning-curve exponents appeared to be functions of soils, equipment, and the managerial expertise of the contractors.

No data to classify the expertise existed; therefore calculations were restricted to soils and equipment. Both derived equations gave statistically satisfactory results.

Substitution of I and E into the RoA equation permits the hr/ft to be calculated. Two methods were used to calculate the tunneling (operating) hours: integration and summing of finite units of tunneling feet.

The RoA equation (6.3) is derived in Section 6.3. For the purpose of this discussion, consider the equation to be of the form

$$hr/ft = I\,(\Sigma\ ft)^{E}\,(F) \tag{5.6}$$

where: hr/ft = Average time to excavate during a specific distance of the tunnel's length.

I & E = Intercept and learning curve exponent

F = A consolidation of all correction factors.

Calculation of the tunneling hours requires that the tunnel be broken into sectors of roughly equivalent soil expectations. Correction factors are then calculated for each sector. The weekly averages were used here.

5.4.2 Integration Method

Equation (5.6) is integrated between stations d and d+i along the tunnel. Each sector is considered. The tunneling hours are calculated by

$$hrs_{ii} = I\,F_i \int_{d}^{d+i} (\Sigma\ ft)^{E}\, d\,(ft) \tag{5.7}$$

to obtain

$$hrs_{ii} = \frac{I\,F_i}{E+1}\,(\Sigma ft)^{E+1}\Big]_{d}^{d+i} \tag{5.8}$$

Total tunneling hours are the sum of the sector hours

$$\text{Total Hours} = \sum_{i=1}^{j} (hr)_i \tag{5.9}$$

5.4.3 Summation Method

The only difference in summation is the calculation of the sector hours; they are now estimated by using equation (5.6) directly and multiplying by the number of feet, m, in the sector, i.

$$hrs_{is} = ft_i \, I \, F_i \, (\Sigma \, ft_d + 0.5 \, ft_i)^{E} \tag{5.10}$$

The modification to the variable Σft is due to the RoA derivation useing the average rate during a sector having average correction characteristics. To conform to this logic, the cumulative feet of progress were taken to be half the distance m in sector i plus the total distance excavated up to the beginning of sector i. Total tunneling hours are as in equation (5.9).

The two methods of estimating the total tunneling hours are shown, for each tunnel analyzed, in Appendix A-3.

5.4.4 Total Down Time

To estimate the total hours required to excavate the entire length of the tunnel, the amount of non-tunneling hours due to equipment failures and administrative shutdowns must be added to the tunneling hours. Total down time was fitted to an equation of the form shown in Figure 5-4. Because of the random nature of the failures, the equation fit

is less satisfactory, statistically, than other derived equations. The results, on a tunnel-by-tunnel basis, are shown in Appendix A-4.

It was intended to derive equations to describe the failure rates of the various excavation systems; i.e., the shield, the rotating wheel/ digger arm, the mucking system, etc. Although the information is available in the data bank, insufficient time and resources precluded their derivations. Certain of these downtimes are needed in the RoA equation; e.g., shield, excavating equipment, misc. and administrative down hours/ft of advance. In addition, they are also needed to estimate maintenance costs. The latter could not be found as a separate category. Until the equations become available, the program user will continue to rely on his own data and that published by the AGC in their Contractors' Equipment Manual (7th Ed. 1974).

5.4.5 Total Hours

Total hours is the sum of tunneling and downtime hours. On a tunnel-by-tunnel basis, Appendix A-5 shows total hours, by both the integration and summing methods compared with actual hours.

5.4.6 Variability of Predictions

The only certainty about estimating is that a single monetary projection is bound to be too high or too low when compared to the final actual costs. A more useful estimate will cover the range into which the final results will probably fall. The range may be estimated subjectively by the estimator using the knowledge and background of those familiar with the task to be performed. Or, as will be discussed here, it may be quantitatively estimated from the errors of estimate produced from the statistical procedures used in deriving the equations.

A method of imputing the range is known as Monte Carlo simulation.[8] In this procedure, an equation is solved many times, and each time the equation is solved, each independent variable's coefficient is randomly

changed within the confines of each coefficient's statistical variation. In this manner, the equation, or process series, is solved enough times to permit the estimation of the distribution of the answers. The curve in the lower left corner of Figure 5-1 illustrates the result of such a simulation.

The weekly progress rate, in hr/ft., is an example of tunneling variability. The median progress value is that rate most likely to occur. However, there is approximately a 50-percent chance that this value will be exceeded. Note that Figure 5-10 is not a normal distribution; it is approximately log normal. The cumulative distribution of these data is shown in Figure 5-11 where the median RoA was 0.60 hr/ft (1.67 ft/hr). At the 80-percent probability level, the RoA was 1.125 hr/ft (0.89 ft/hr) or less. And at the 20-percent probability level, the RoA was 0.325 hr/ft (3.08 ft/hr) or less.

The variability of the tunneling hours, using equation (5.8), would now be estimated, for the integration method, by

$$hrs_{ii} = \left[\frac{(I \pm r_1 \sigma_I)\, e^{(Ln\, F_i \pm r_2 \sigma_F)}}{(E \pm r_3 \sigma_E) + 1} (\Sigma\, ft)^{(E \pm r_3 \sigma_E) + 1} \right]_{d}^{d+i} \qquad (5.11)$$

and for the summation method, by

$$hrs_{is} = ft_i\, (I \pm r_1 \sigma_I)\, e^{(LnF_i \pm r_2 \sigma_F)} (\Sigma\, ft_d + 0.5\, ft_i)^{(E \pm r_3 \sigma_E)} \qquad (5.12)$$

where:

r = random normal deviate

σ = standard error of estimate of the individual predicting equations

Total downtime hours are calculated by

$$D\, hrs_i = ft_i\, e^{(Ln\, DH_1 \pm r\, \sigma_{DH})} \qquad (5.13)$$

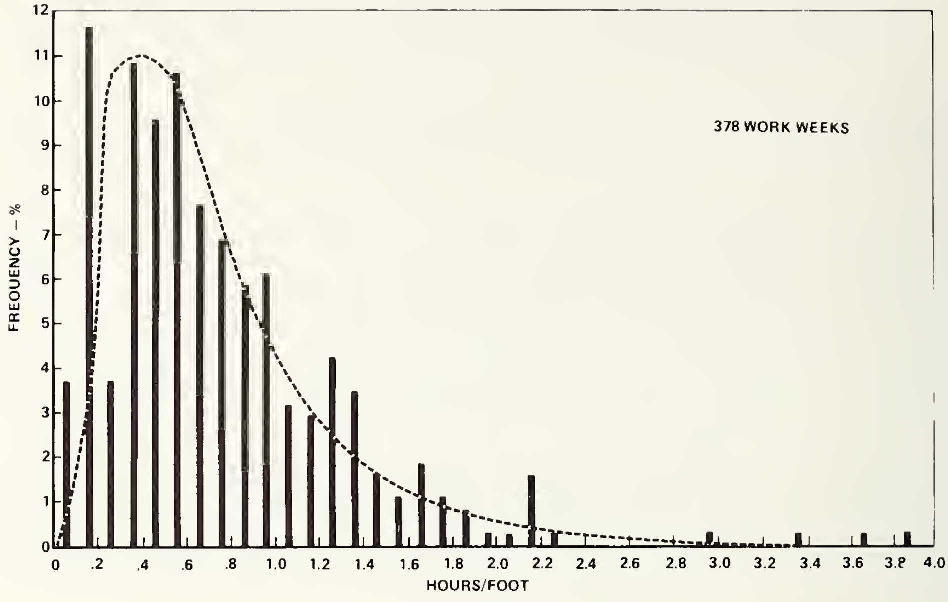


Figure 5-10. Distribution of Weekly Average Rates of Advance

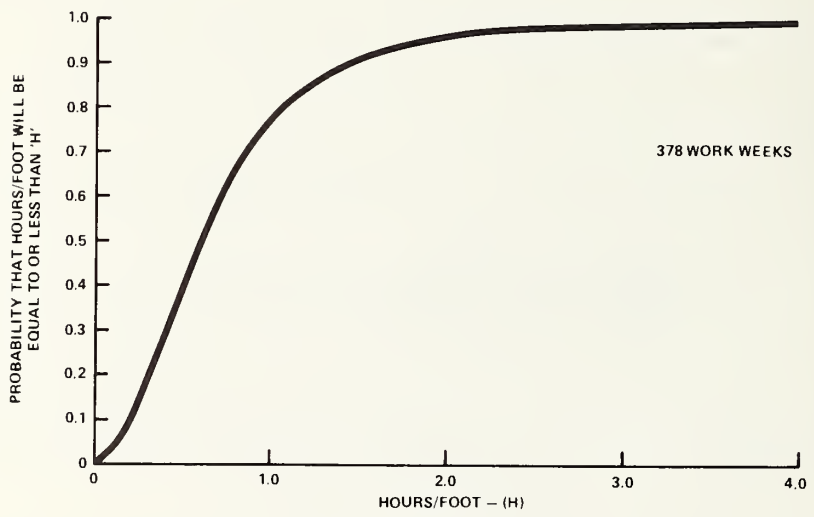


Figure 5-11. Cumulative Distribution of Weekly Average Rates of Advance

Equations (5.11) through (5.13) calculate the distribution of hours for sector i. To obtain the total hours over the tunnel's length, equation (5.9) is increased to include the individual sectors' variability. To do this it will be necessary to calculate the variance of the estimate for each sector, i, sum the variances over the sectors, and then take the square root of the sum. This is the standard error of estimate of the total hours.

$$\sigma_i^2 = \frac{\Sigma\,(hr_i^2) - (\Sigma\, hr_i)^2/N}{N-1} \tag{5.14}$$

where; hr_i = Hours calculated for sector i

N = Number of iterations used to calculate the distribution of hours

The total hours variation, or standard error, is

$$\sigma_{\Sigma\, hr} = \left[\sum_{i=1}^{j} (\sigma^2)_i\right]^{0.5} \tag{5.15}$$

Equation (5.9) is now modified by adding the results of equation (5.15) to obtain

$$\text{Total hours} = \sum_{i=1}^{j} (hr)_i \pm \left[\sum_{i=1}^{j} (\sigma^2)_i\right]^{0.5} \tag{5.16}$$

The distribution of total in-the-hole hours is calculated from equation (5.16).

The above means of estimating the tunneling and downhours are based on random occurrences during normal operations; extraordinary events were excluded from the analysis. For instance, on one pair of parallel tunnels, the shield passed through shafts at 12.5 and 44.5 percent of the total tunnel distance. The contractor opted to spend about two weeks at each shaft on each tunnel for shield and excavator wheel maintenance and modifications. In addition, when the shields were within 200 feet of the tunnels' ends, forward progress was halted as the station was not ready for the breakthrough.

5.4.7 Other Costs

After the total shift hours are estimated, crew staffing and current labor costs are combined to estimate the labor cost distribution. Data on staffing were obtained for most of the tunnels. Properly, the possible variance in both the staffing and labor costs are estimated and combined with total hours variance, using the technique of the propagation of error (variance), to calculate the labor cost distribution.

The parameters of tunnel length, anticipated soil characteristics, and primary liner types are expected to influence the selection of equipment for excavation and mucking.

In the time available, maintenance costs, either total or on individual items of equipment, could not be found. It is not known whether these costs are individually itemized or are buried in other operating costs.

The effect of not quantifying crew, equipment, and maintenance costs, either because all or part of the data were not available or could not be found, results in a void in the calculation procedure. These data are normally available to contractor's estimators from the contractor's properietary information data bank. The disadvantage to the proposed calculation procedure is that the information can not be weighed to benefit from the experience of many tunneling operations. We believe that future studies should find and analyze these histories.

6. PREDICTING EQUATIONS

Derivation of the predicting equations was accomplished by stepwise multiple regression. The first equation computer run, after eliminating variables that logic suggested should not be included, was to determine the correlation coefficients between the individual remaining independent variables and those data sets that appeared to be outliers (due to a lack of explanatory variables or just poor data). Outlier data were eliminated on the preliminary tunnel-by-tunnel runs.

A technique used to reduce intercorrelation between variables is to create new variables by adding and subtracting; e.g., if X_1 and X_2 are highly correlated, it may be possible to find coefficients for each that are less correlated or completely independent by adding the new variables X_3 and X_4 to the regression matrix, where

$$X_3 = X_1 + X_2$$

$$X_4 = X_1 - X_2$$

If the regression results included all four variables, such that

$$Y = a + b X_1 + cX_2 + d X_3 + e X_4,$$

the resulting coefficients for X_1 and X_2 would be for

$$X_1: \quad b + d + e$$

and for

$$X_2: \quad c + d$$

The above technique was used for all correlation coefficients > $\pm$ 0.3. Unfortunately, this procedure does not directly give coefficient standard errors of estimate. In the example above, an error of estimate is calculated for all four variables.

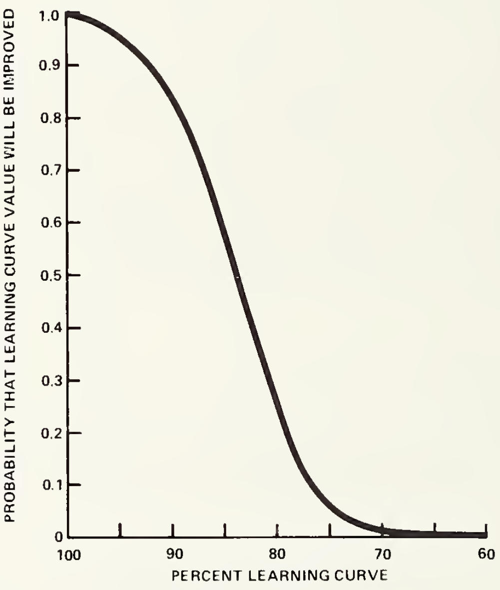


Figure 6-1. Distribution of Learning Curve Values

6.1 THE RATE OF ADVANCE EQUATION LEARNING CURVE EXPONENT

The Learning Curve Exponent varied from tunnel to tunnel; the average for the 21 tunnels was -0.281 (an 82.3 percent curve) with a standard deviation of 0.071. The cumulative distribution of the exponents found is shown in Figure 6-1. Because of the large variation in the exponent, a means of predicting is required. Managerial control undoubtedly has a large influence on the exponent (a measure of productivity) but was unknown for analytical purposes. We were quite aware of the potential value of such a subjective measure of supervisory control; however, in past attempts to quantify this variable after-the-fact, it was found that the inclusion was usually statistically nonsignificant. Nor did personnel want their gradings recorded. The subject is noted here to signify that the variable was recognized as meaningful.

In section 3.1 it was stated that the symbols $1 \rightarrow 2$ and 1/2 mean that a parameter either has an assigned value which varies between 1 and 2 or has a yes/no value of 1 or 2. The 1,2 variation was chosen for computational reasons rather than a 0,1 range, and is used in this and subsequent derived equations.

Equation (6.1) gives some quantitative insight into the effects of the independent variables on the rate of productivity increase. For instance,

- Increasing the work week from 40 to 80 hours is about a 19% increase in the exponent. A further increase to a 120-hour work week has a marginal increase of only about 9 percent. The rationale might be that the discontinuance of starting and stopping daily operations is reflected in the tunneling productivity exponent.

- Tunneling in running water (a value of 1.75 assigned) vs tunneling in moist ground (1.25) reduces the productivity rate exponent by approximately 250 percent.

- The productivity exponent is bettered by increasing the jacking potential, and it is reduced with the cross section area of the shield.

- Except for the coefficients for soil cobbles and boulders, and for peat and trash (for which there were insufficient data), the effects of soils on the productivity rate can be estimated.

Table 6-1 shows the exponent observed for the individual tunnels, the predicted value, and their differences.

LEARNING CURVE EXPONENT = –0.5538 – 0.00938 *

Ln (Total Shift Hr/Wk) + 0.03025 * Ln (Silt and Clay: 1 → 2) – 0.03271 *

Ln (Cobbles and Boulders: 1 → 2) + 0.06094 * Ln (Cemented Ground: 1 → 2) – 0.23648 *

Ln (Peat and Trash: 1 → 2) + 0.03254 * Ln (Cohesive Ground: 1 → 2) – 0.03254 *

Ln (Running Ground: 1 → 2) + 0.02192 * Ln (Water Running at Face: 1 → 2) – 0.05555 *

Ln (Tunnel Working Pressure – Psia) – 0.03964 * Ln (Jacking Potential – Tons/ft^2)

+ 0.17693 * Ln (OD of Shield – ft) + 0.04705 *

Ln (Shield and Wheel: 1/2) + 0.05597 * Ln (Shield and Digger Arm: 1/2) – 0.04746 *

Ln (Conveyor Belt and Truck: 1/2) + 0.04705 * Ln (Rubber Tired Muck Vehicle: 1/2);

$S_y = 0.051 \qquad R^2 = 0.9699$ (6.1)

Table 6-1

COMPARISON OF ESTIMATED AND PREDICTED
LEARNING CURVE EXPONENT

System	Contract	Tunnel	Observed Value	Predicted Value	Difference
BART	1M0031	MR	-0.2920	-0.2875	-0.0045
BART	1M0031	ML	-0.2501	-0.2741	0.0240
BART	1R0053	RR/RL	-0.2343	-0.2461	0.0018
BART	1S0011	TR	-0.2706	-0.3215	0.0509
BART	1S0011	TL	-0.3977	-0.2904	-0.1073
BART	1S0011	SR	-0.2363	-0.2805	0.0442
BART	1S0011	SL	-0.3621	-0.3295	-0.0326
BART	1S0051A	SR	-0.3404	-0.3472	0.0068
BART	1S0051A	SL	-0.3940	-0.3317	-0.0623
Chicago	68-404-2S	USC #1	-0.4016	-0.3345	-0.0671
Chicago	68-405-2S	USC #2	-0.3385	-0.3391	0.0006
Chicago	68-406-2S	USC #3	-0.2415	-0.3215	0.0800
WMATA	1F0021	F2A Out	-0.2764	-0.2578	-0.0186
WMATA	1F0021	F2A In	-0.2192	-0.2607	0.0415
WMATA	1F0021	F2ABR Out	-0.2589	-0.2811	0.0222
WMATA	1F0021	F2ABR In	-0.3158	-0.2777	-0.0381
WMATA	1F0012	F1B No. Out	-0.2229	-0.1914	-0.0315
WMATA	1F0012	F1 No. In	-0.2673	-0.2324	-0.0349
WMATA	1F0012	F1 So. Out	-0.1287	-0.1825	0.0538
WMATA	1F0012	F1B So. In	-0.2055	-0.1839	-0.0216
WMATA	1D0091	D9 So. In	-0.2476	-0.2268	-0.0208

Based on Individual Tunnels, the:

Standard Error of Prediction: 0.0462

Amount of variability Removed by Predicting Equation: 55.4%

6.2 THE RATE OF ADVANCE EQUATION INTERCEPT

Each tunnel not only had a different learning curve exponent, but also had a different intercept value (the theoretical time to mine the first foot). The mean value of all the data was 3.815 with a standard deviation of 2.557 hr/ft. The cross tunnel computer run was made prior to the inclusion of all the data (322 data sets vs 388 finally available). Time and resources prevented a final run.

The derived equation (6.2) is given below. Table 6-2 shows the individual tunnel's observed intercept as well as that predicted.

$$\text{Intercept} = 0.4121 * \begin{pmatrix}\text{Silt and Clay}\\ 1 \rightarrow 2\end{pmatrix}^{0.2215} * \begin{pmatrix}\text{Clay and Sand}\\ 1 \rightarrow 2\end{pmatrix}^{0.1216} *$$

$$\begin{pmatrix}\text{Sand and Gravel}\\ 1 \rightarrow 2\end{pmatrix}^{0.1928} * \begin{pmatrix}\text{Peat and Trash}\\ 1 \rightarrow 2\end{pmatrix}^{-1.2698} * \begin{pmatrix}\text{Cemented Ground}\\ 1 \rightarrow 2\end{pmatrix}^{0.146} *$$

$$\begin{pmatrix}\text{Cohesive Ground}\\ 1 \rightarrow 2\end{pmatrix}^{0.208} * \begin{pmatrix}H_2O\text{ at Face}\\ 1 \rightarrow 2\end{pmatrix}^{0.2069} * \begin{pmatrix}\text{Tunnel Pressure}\\ 1 \rightarrow \overset{\text{psia}}{2}\end{pmatrix}^{-0.1276} *$$

$$\begin{pmatrix}\text{Running Ground}\\ 1 \rightarrow 2\end{pmatrix}^{0.3538} * \begin{pmatrix}\text{Shield and Wheel}\\ 1 \rightarrow 2\end{pmatrix}^{0.0716} * \begin{pmatrix}\text{Shield and Digger arm}\\ 1 \rightarrow 2\end{pmatrix}^{0.2068} *$$

$$\begin{pmatrix}\text{Shield and Manual Digging}\\ 1 \rightarrow 2\end{pmatrix}^{0.5694} * \begin{pmatrix}\text{Conveyor Belt and Train}\\ 1/2\end{pmatrix}^{-0.2784} *$$

$$\begin{pmatrix}\text{Conveyor Belt and Truck}\\ 1/2\end{pmatrix}^{-0.4136} * \begin{pmatrix}\text{Rubber Tired Vehicle}\\ 1/2\end{pmatrix}^{1.5395} *$$

$$\begin{pmatrix}\text{Ribs and Lagging}\\ 1/2\end{pmatrix}^{-1.1369} * \begin{pmatrix}\text{Concrete Pipe Jacked In}\\ 1/2\end{pmatrix}^{-2.6217} * e^{-7.3957 * E}$$

$$R^2 = 0.925, \quad \text{Ln } S_Y = 0.1956 \qquad (6.2)$$

Table 6-2

COMPARISON OF ESTIMATED AND PREDICTED
RATE OF ADVANCE INTERCEPT

System	Contract	Tunnel	Observed Value	Predicted Value	Difference
BART	1M0031	MR	2.497	2.692	-0.195
BART	1M0031	ML	2.391	2.689	-0.298
BART	1R0053	RR/RL	9.314	10.661	-1.347
BART	1S0011	TR	3.035	5.045	-2.010
BART	1S0011	TL	6.754	5.368	1.386
BART	1S0011	SR	2.811	3.823	-1.012
BART	1S0011	SL	7.856	5.136	2.720
BART	1S0051	SR	7.134	6.338	0.796
BART	1S0051	SL	8.553	10.639	-2.086
Chicago	68-404-2S	USC #1	3.476	1.961	1.515
Chicago	68-405-2S	USC #2	0.722	0.716	0.006
Chicago	68-406-2S	USC #3	0.783	1.675	-0.892
WMATA	1F0021	F2A Out	2.390	3.194	-0.804
WMATA	1F0021	F2A In	2.353	3.624	-1.271
WMATA	1F0021	F2ABR Out	1.811	2.488	-0.677
WMATA	1F0021	F2ABR In	2.928	3.007	-0.074
WMATA	1F0012	F1B No. Out	3.083	2.431	0.652
WMATA	1F0012	F1B No. In	3.456	2.872	0.584
WMATA	1F0012	F1B So. Out	1.776	2.398	-0.622
WMATA	1F0012	F1B So. In	2.108	2.453	-0.345
WMATA	1D0091	D9 So. In	4.879	4.217	0.662

Based on Individual Tunnels, the:

Standard Error or Prediction: 1.201

Amount of Variability Removed by Predicting Equation: 76.8%

Some conclusions that can be inferred about the initial Rate of Advance from the equation are:

- Relative to the clay and sand category,
  - silt and clay is about 7 percent slower,
  - sand and gravel is about 5 percent slower,
  - cemented ground is about 2 percent slower,
  - cohesive ground is about 6 percent slower,
  - running ground is about 17 percent slower.
- Compared with the rotating cutting wheel, and where soil conditions will permit alternate excavation methods,
  - the digger arm is about 10 percent slower,
  - manual digging is about 41 percent slower
- Compared with a conveyor belt and tram for muck removal,
  - a conveyor belt and truck are about 9 percent faster,
  - a rubber-tired vehicle is about 35 percent slower.
- The initial rate is inversely proportional to the learning curve exponent (E).

6.3 RATE OF ADVANCE EQUATION

The large matrix size, 115 real and created variables, required the location of a computer program with larger capacity. The time delay reduced the time available for analysis. Although equation (6.3) predicts with a high degree of accuracy, improvements can be made by manipulation of data and the inclusion of new types of soils (no glacial till soils were included).

The predicting equation (6.3) is given below. Table 6-3 shows the standard error of estimate, based on equation (6.3), for each tunnel.

$$
\begin{aligned}
\text{Hr/Ft} = I\,(\Sigma \text{Ft})^{E} * \Bigg[& \left(\frac{\text{Total Dwn Hr}}{\text{Ft}} + 1\right)^{0.4095} * \left(\frac{\text{Shield Dwn Hr}}{\text{Ft}} + 1\right)^{0.1088} * \\
& \left(\frac{\text{Excav. Equip Dwn Hr}}{\text{Ft}} + 1\right)^{0.4095} * \left(\frac{\text{Misc. Dwn Hr}}{\text{Ft}} + 1\right)^{-0.3783} * \left(\frac{\text{Admin Dwn Hr}}{\text{Ft}} + 1\right)^{0.643} * \\
& \left(\frac{\text{Silt \& Clay}}{1 \rightarrow 2}\right)^{-0.192} * \left(\frac{\text{Clay \& Sand}}{1 \rightarrow 2}\right)^{-0.192} * \left(\frac{\text{Sand \& Gravel}}{1 \rightarrow 2}\right)^{0.2468} * \\
& \left(\frac{\text{Cobbles \& Boulders}}{1 \rightarrow 2}\right)^{-0.1753} * \left(\frac{\text{Cemented Grnd}}{1 \rightarrow 2}\right)^{0.25} * \left(\frac{\text{Cohesive Grnd}}{1 \rightarrow 2}\right)^{-0.22} * \\
& \left(\frac{\text{Running Grnd}}{1 \rightarrow 2}\right)^{0.22} * \left(\frac{\text{Jacking Potential}}{\text{Tons / Ft}^2}\right)^{-0.1766} * \left(\frac{\text{O D Shield}}{\text{Ft}}\right)^{0.942} * \\
& \left(\frac{\text{Shield \& Digger Arm}}{1/2}\right)^{-0.138} * \left(\frac{\text{Shield \& Manual Digging}}{1/2}\right)^{0.1284} * \\
& \left(\frac{\text{Convyr Belt \& Train}}{1/2}\right)^{0.58} * \left(\frac{\text{Rubber Tired Vehicle}}{1/2}\right)^{-0.41} * \left(\frac{\text{Ribs \& Lagging}}{1/2}\right)^{0.438} * \\
& \left(\frac{\text{Concrete Pipe}}{1/2}\right)^{1.105} * \left(\frac{\text{Last Week}}{1/2}\right)^{0.8074} * \quad 0.10377 \Bigg]
\end{aligned}
$$

$S_Y = 0.294 \quad R^2 = 0.72$ (6.3)

$\text{Ln } S_F = 0.4094$ (the variables between the square brackets)

Table 6-3

RATE OF ADVANCE PREDICTION ERROR OF ESTIMATE

Tunnel System	Contract	Tunnel Number	Standard Error Relative to Equation 6.3
BART	1M0031	MR	.277
	1M0031	ML	.204
	1R0053	RR/RL	.358
	1S0011	TR	.429
	1S0011	TL	.587
	1S0011	SR	.279
	1S0011	SL	.493
	1S051A	SR	.305
	1S051A	SL	.391
Chicago	68-404-2S	USC #1	.218
	68-405-2S	USC #2	.159
	68-406-2S	USC #3	.041
WMATA	1F0012	F1B No. Out	.242
	1F0012	F1B No. In	.452
	1F0012	F1B So. Out	.232
	1F0012	F1B So. In	.177
	1F0021	F2A Out	.279
	1F0021	F2A In	.293
	1F0021	F2A B.R. Out	.253
	1F0021	F2A B.R. In	.257
	1D0091	D9 So. In	.403

Average 0.270

Amount of variability removed by predicting equation 71.8%

The errors are logarithmically distributed. USC #3 is not in the log normal distribution; without USC #3, the Mean = 0.297.

Some interesting observations may be made relative to the effect of certain correction factors.

Equation (6.3) suggests that soils effects on the RoA, from greatest impediment to greatest ease of progress, would be: cemented ground, sand and gravel, running ground, cobbles and boulders, silt, clay and sand mixes, cohesive ground. Logic doesn't support the above order. The cobbles and boulders should be a higher order and probably resulted in its position (and exponent) due to interactions with more favorable conditions in the few data sets in which they appeared. Statistically, considering the numerical values of the derived exponents and their individual errors of estimate, the first three soils are different from the last three, but in the two groups of three there is not much difference.

The RoA is increased with increasing jacking potential and decreased with increasing diameter of the shield.

The last week of tunneling is inefficient relative to the RoA.

There are correlation interactions between the various down times as well as the equipment in use. Table 6-3 shows the standard error of estimate by individual tunnels.

6.4 TOTAL DOWNTIME EQUATION

Total downtime per foot of mining was not a good prediction — the event appears to be too random. Reliability theory suggests that a U-shaped curve, Figure 5-4, should describe the events with time, and the regression, equation (6.4), was done in that form. However, because of the poor fit of the equation, it is suggested that the average downtimes, hr/ft, may be used. For all equipment failures, the averages are shown in Table 6-4.

$$
\begin{aligned}
&(\text{TOTAL DOWN HOURS} + 0.001)/\text{Ft} = 4.5054 \times 10^{-3}\ \text{Exp}[-5.0536 \times 10^{-5} * (\Sigma\text{Ft}) - 1.3573 \times 10^{-7} * \\
&(\Sigma\text{Ft})^2 + 2.1773 \times 10^{-11} * (\Sigma\text{Ft})^3 + 0.85647 * (\text{Silt and Clay: } 1 \rightarrow 2) + 0.67523 * \\
&(\text{Clay and Sand: } 1 \rightarrow 2) + 0.82934 * (\text{Sand and Gravel: } 1 \rightarrow 2) + 0.30376 * \\
&(\text{Cobbles and Boulders: } 1 \rightarrow 2) - 1.27427 * (\text{Cohesive Ground: } 1 \rightarrow 2) + 1.28616 \times 10^{-3} * \\
&(\text{Total Jacking Potential of Shield} - \text{Tons}) - 0.18252 * (\text{OD Shield} - \text{Ft}) + 2.66974 * \\
&(\text{Shield and Cutting Wheel: } ½) + 0.80838 * (\text{Shield and Digger Arm: } ½) - 1.46578 * \\
&(\text{Conveyor Belt and Train: } ½) - 0.39557 * (\text{Rubber Tired Truck: } ½)]\,;
\end{aligned}
$$

$$R^2 = 0.174,\ \ \text{Ln}\ S_y = 1.9563 \qquad (6.4)$$

Table 6-4

AVERAGE DOWNTIME — HR/FT

Category	Average Hr/Ft Down	Standard Deviation	σ/μ*
Total Hours	0.1720	0.3718	2.16
Shield	0.0249	0.0878	3.53
Excavating Equipment	0.0440	0.2410	5.48
Conveyor	0.0113	0.0404	3.04
Muck and Other Transportation	0.0166	0.0789	4.75
Miscellaneous	0.0697	0.1459	3.53
Administrative	0.0089	0.0400	4.49

*The coefficient is a relative measure of the variability of the data about the mean. A satisfactory value, for nominal use, would be less than 0.5.

A further investigation into the total down hours is shown in Figure 6-2. The plot between cumulative total down hours and cumulative feet of tunnel suggests a relationship that could be developed and would involve the cumulative history of soils penetrated, and the equipment types in use, as well as the shield diameter and jacking potential in tons/ft^2.

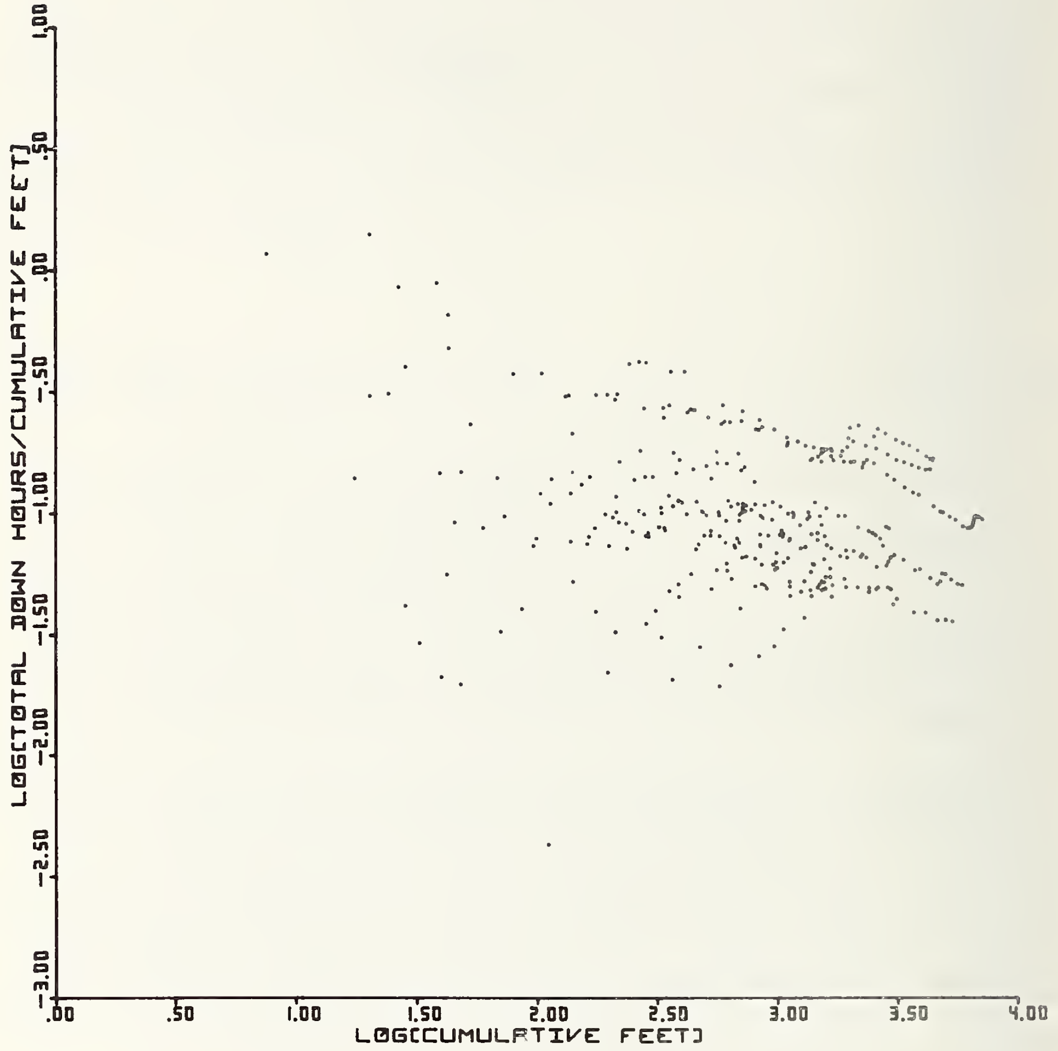


Figure 6-2. Total Downtime as Related to Cumulative Feet of Tunneling

6.5 OTHER DOWN HOURS

The "other equipment down hours" were investigated plotwise and are shown merely to display their potential as a means for prediction.

Figure 6-3 shows the downtime for the excavating cutting wheel used on the Chicago USC No. 1 tunnel.

Figures 6-4, 5(a), 5(b), 6 and 7 indicate the cumulative downtime hours vs cumulative tunneling feet for the shield, excavating equipment, miscellaneous, and administrative down hours.

Statistical analysis of these data would likely develop usable predicting equations except for predicting the shield and administrative down hours. These events appear to be completely random.

The conclusion that may be drawn from Figures 6-2 to 6-7 is that

- There appears to be a linear relation between down hours and cumulative distance of tunneling (time) for total down hours, excavating equipment, and miscellaneous hours. Statistical analysis of the data would be expected to result in a useful predicting equation,

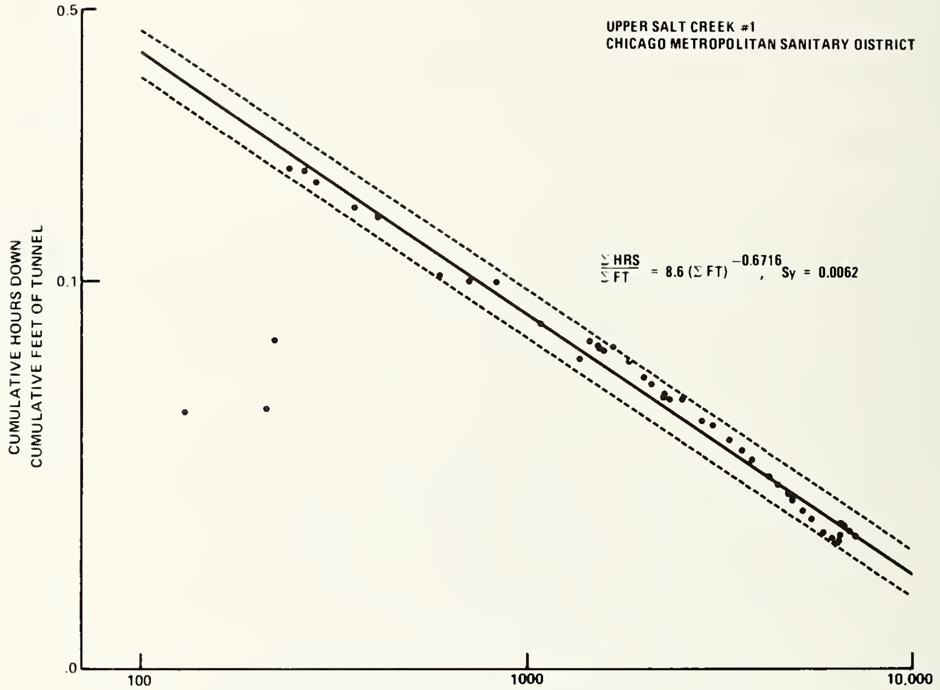
- The shield and administrative down hours appear to be random events not correlated with tunneling distance (time). Under these circumstances, the mean and standard deviation of downtime (Table 6-4) is a satisfactory means of estimation.

The disadvantage of using a mean downtime for equipment that shows wear-out characteristics is that:

- Short tunnels will be overstated for downtime

- Long tunnels will show too much downtime at the beginning and insufficient downtime at the end.

The argument for further analysis is pervasive.



Cumulative Feet of Tunnel

Figure 6-3. Excavating Cutting Wheel Downtime for USC No. 1

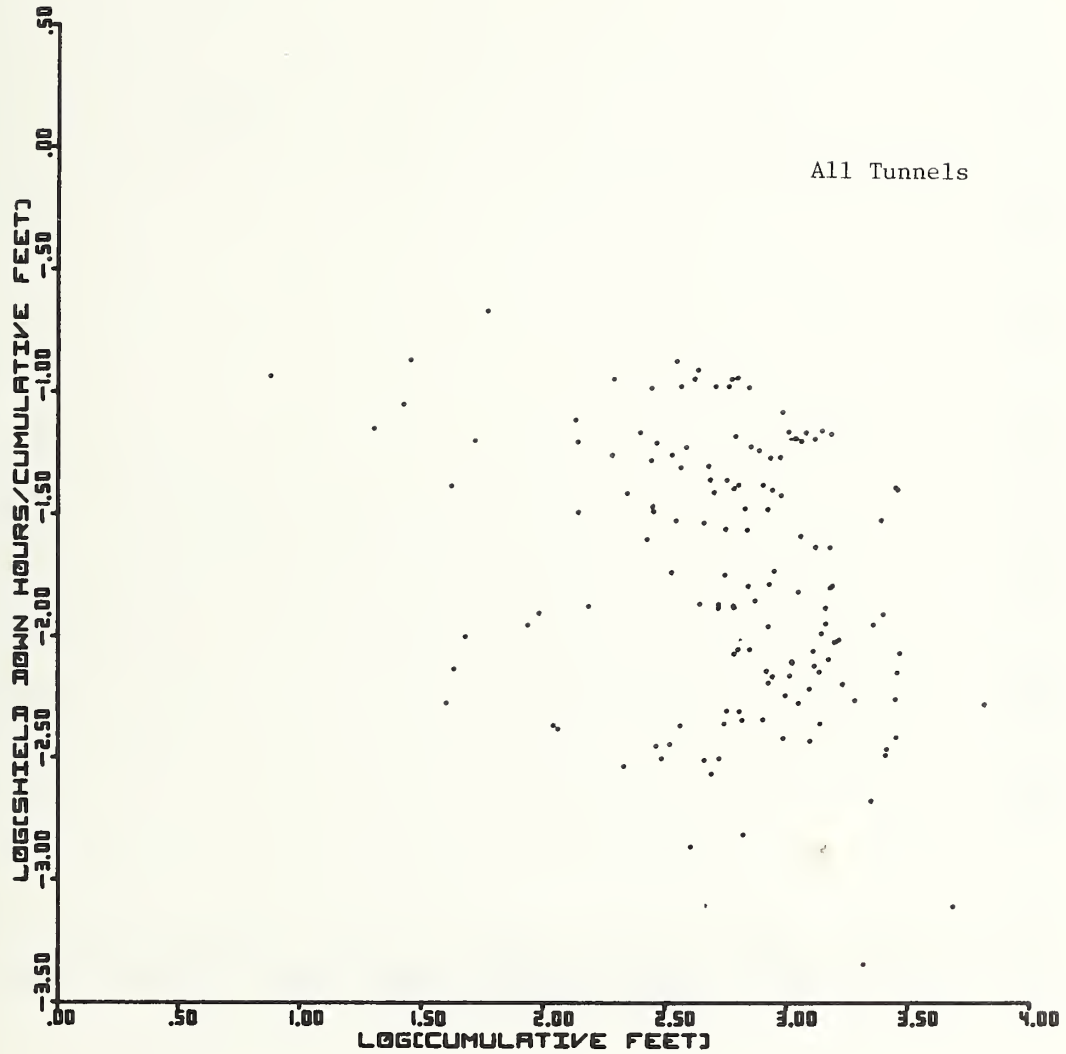


Figure 6-4. Shield Downtime

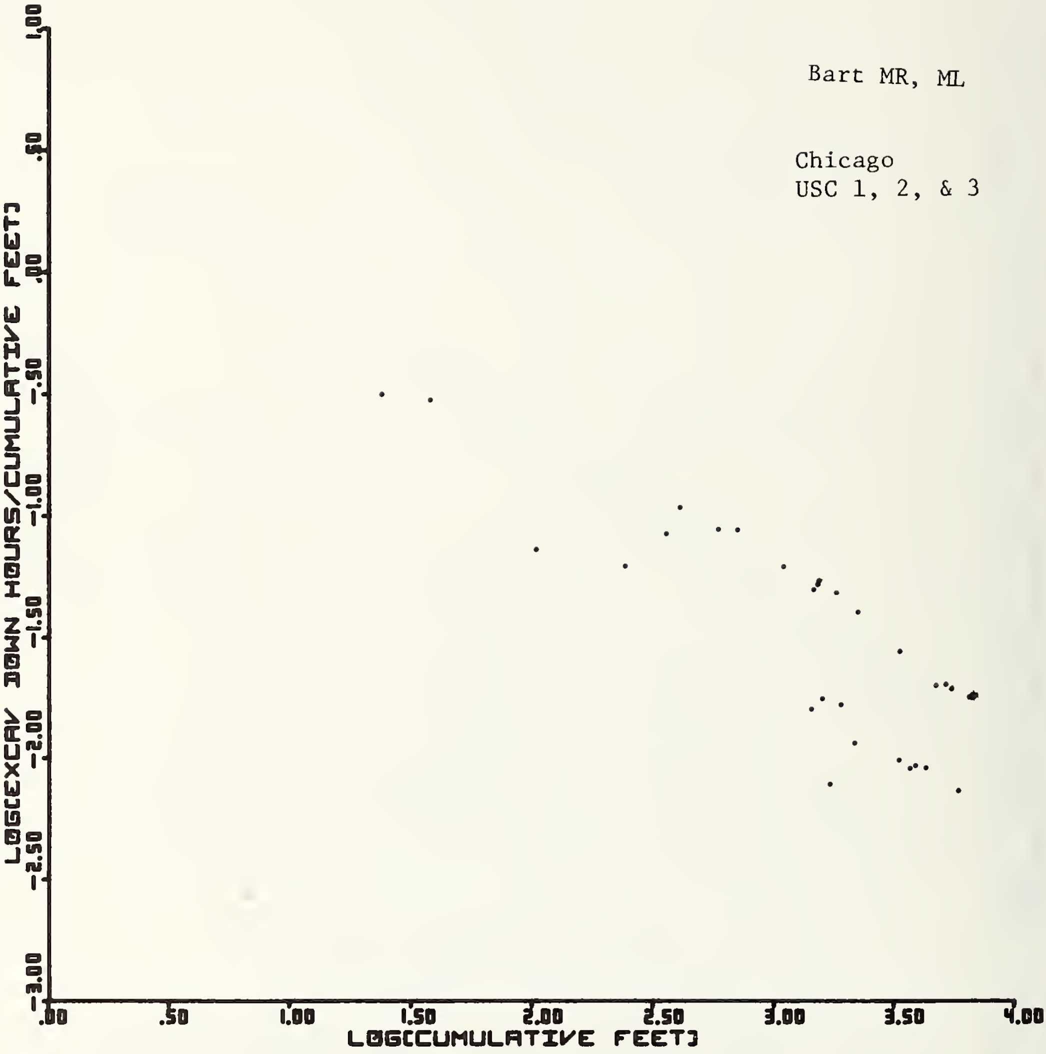


Figure 6-5A. Rotating Cutting Wheel
Downtime

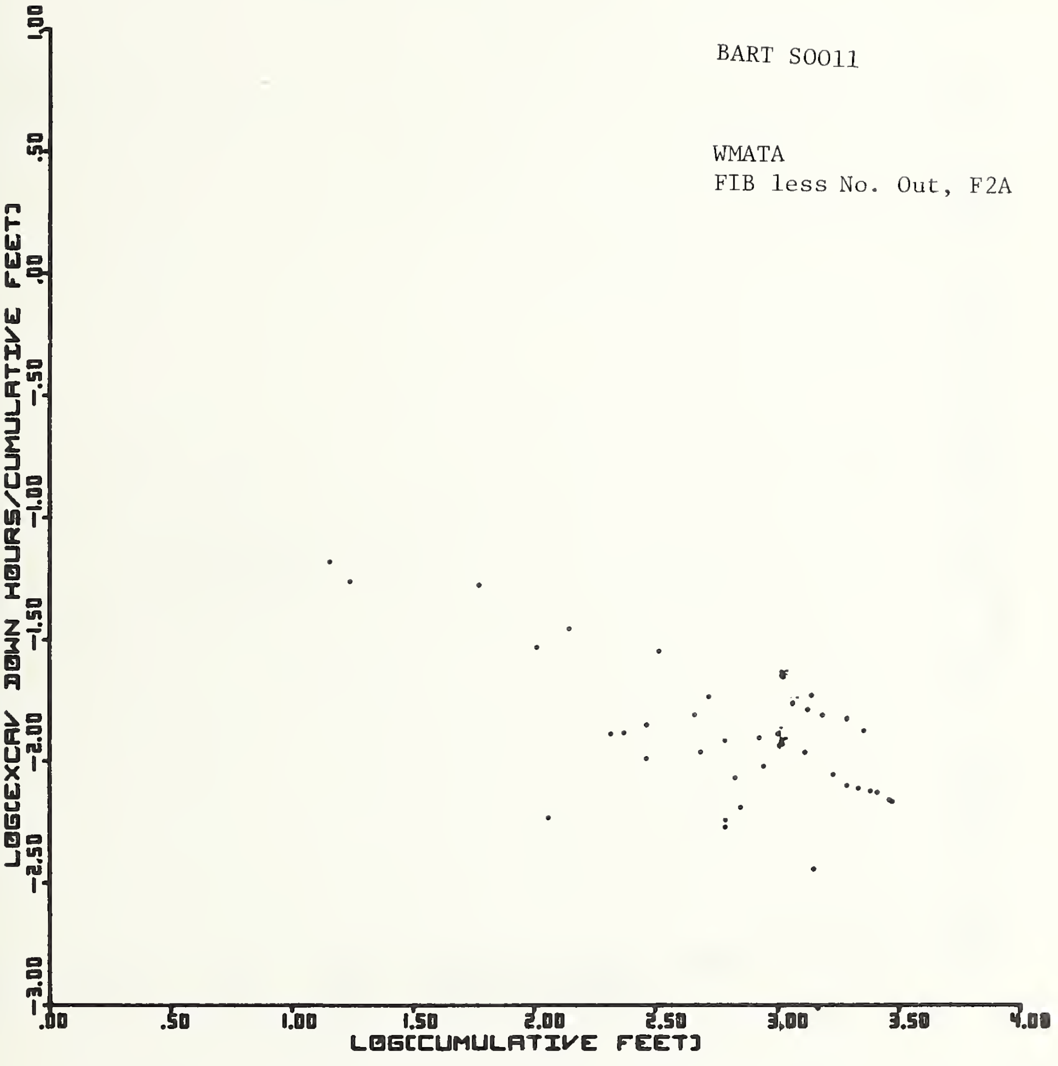


Figure 6-5B. Digger Arm Downtime

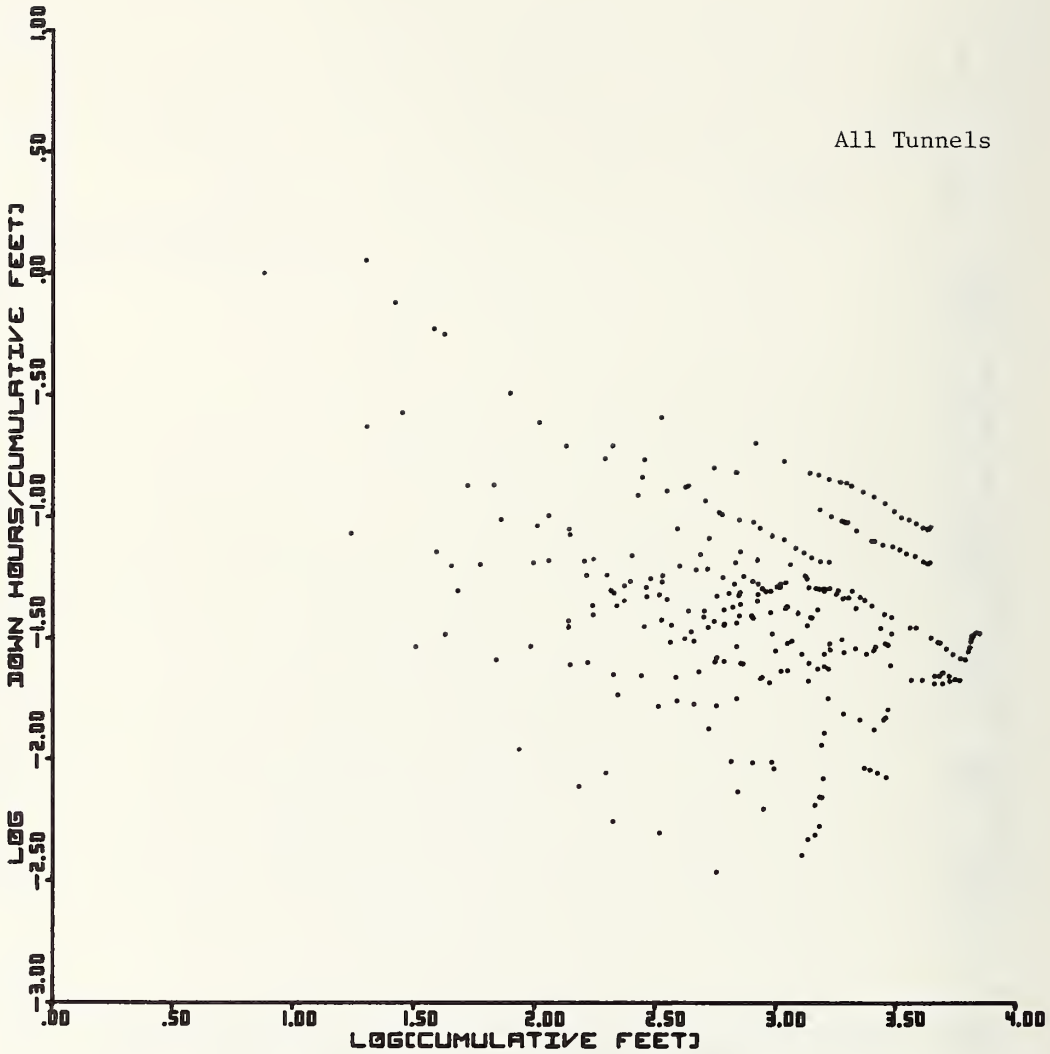


Figure 6-6. Miscellaneous Downtime

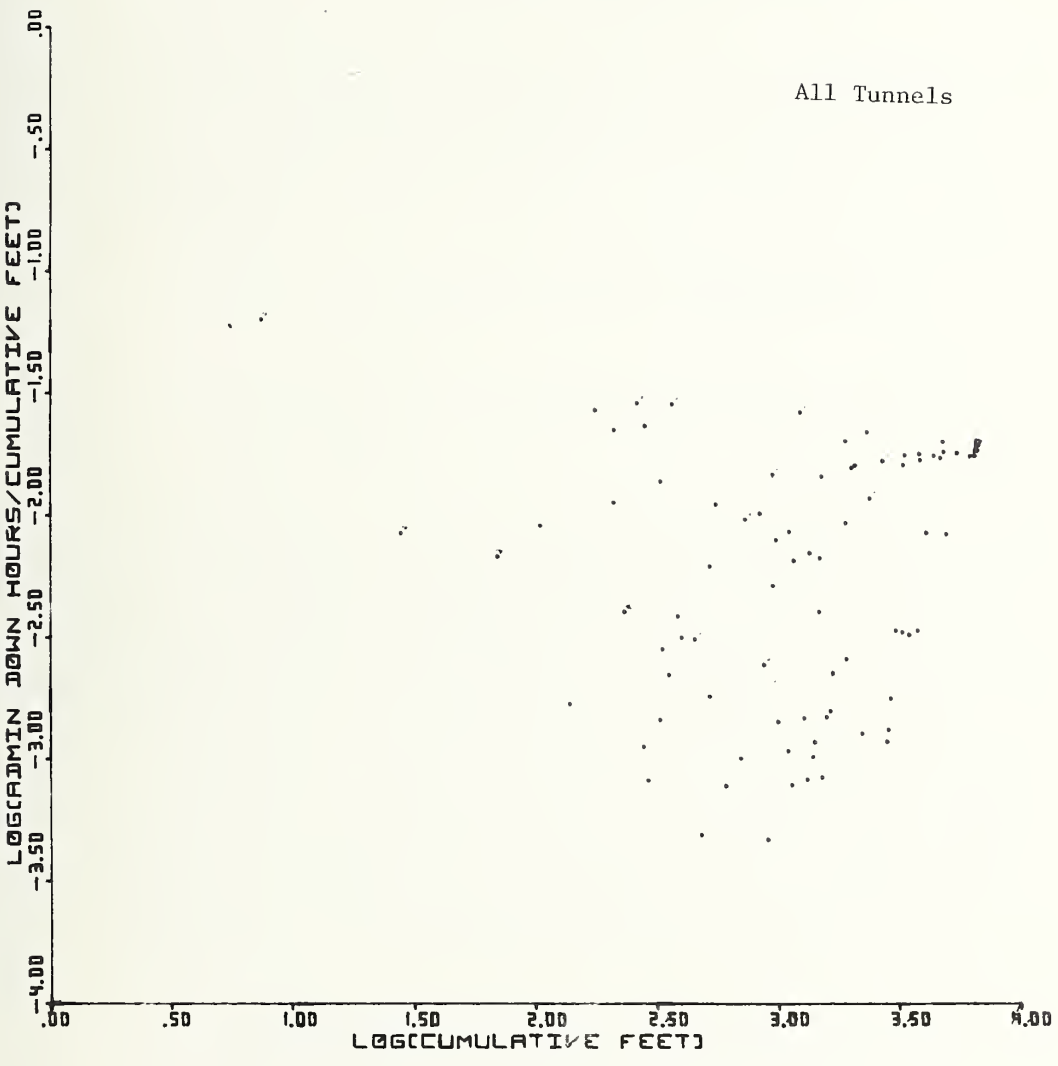


Figure 6-7. Administrative Downtime

7. INSTITUTIONAL EFFECTS

Institutional effects are those factors, usually subjective, that are applied as multipliers to the direct labor costs to allow for identified parameters with unknown or partially known ranges of variability. In the categories of

- Risk — an action with a known set of outcomes and each outcome occurring with a known probability distribution; and

- Uncertainty — an action with a known set of outcomes, but each outcome occurs without a known probability distribution

institutional effects fall into the classification of uncertainty. In order to reduce some of the uncertainty, a number of questions were asked of tunneling contractors relative to the effects of various institutional factors. The results of the analysis of the questionnaire answers have been incorporated into a guideline for planners' use for determining the factors' impact on costs. The factors examined were those deemed most significant in their effect on project costs. Discussions with transit system owners and tunneling contractors by Bechtel's consultant, J.M. Keating, as well as Bechtel's own estimating staff, led to the following selection of eleven major institutional factors.

1. Availability and Analysis of Subsurface Geological Conditions

   This factor covers the extent to which the Owner-engineer has collected, evaluated, and disseminated subsurface information to the contractor prior to the contractor's bid preparation. Included in this information would be any geological interpretations obtained by the Owner-engineer.

2. The Extent of Owner Disclaimers with Regard to Subsurface Information Provided to the Contractors

3. Flexibility of Engineering Specifications

   Flexibility refers to the degree to which the engineering specifications allow for design changes suggested by the contractors to accommodate the selected construction method.

4. Quality of Engineering Specifications

   Quality refers to the accuracy of the Owner-engineer design including assumptions on which the design and specifications are based.

5.A Owner-obtained Rights-of-way

   Rights-of-way include arrangements with all Owners of property, including utilities that must be relocated. Rights-of-way are also construed to include areas needed by the contractor as work and storage areas, including any rights-of-way needed for muck disposal.

5.B Owner-obtained Construction and Entry Permits

   These include permanent and temporary construction permits and entry permits where required.

6. Potential Contractor Liability

   Liability here is used to include only the contractor liability related to changed conditions.

7. Labor Agreements

   The existence of systemwide labor agreements.

8. Labor Union History in the Area

   Included in the history are work practices, craft availability, work stoppages, jurisdictional disputes, and union management relations.

9. Owner Payment and Retention Periods

10. Owner History of Claims Settlements on Past Projects

7.1 DATA COLLECTION AND ANALYSIS

The impact of institutional factors on tunneling costs, for the most part, has a twofold effect. First, there are what we have chosen to call the identifiable costs. These represent, for example, estimated expenditures incurred by the contractor to:

- Collect and evaluate subsurface data where none is provided by the Owner,
- Obtain rights-of-way and construction permits not obtained by the Owner, and
- Cover added financing costs where owner payment periods are excessive or retention amounts excessive .

The second effect of the institutional factors is on contingency costs included by the contractor at the time of bid to cover expenditures that are "likely" to occur during the tunnel drive, but which cannot be quantified at the time of the estimate. Contingency costs are directly related to the risks incurred by the contractor. The greater the risk burden, the greater the contingency costs. This second impact, the impact on contingency costs, is by far the greater of the two and also less visible to the owner.

7.2 DATA

Since current industry practices do not require sufficient detailing of contractor bids to identify contingency costs, an alternate approach was taken to obtain data from which to evaluate institutional cost factors. The questionnaire discussed in paragraph 7.7 was sent to 25 soft-ground tunneling contractors through Bechtel's consultant, to determine the impact of each of the institutional factors on contingency. Since contingency costs are a measure of the contractor's risk and risk is theoretically related to profit, the questionnaire also included several questions relating to profit. Profit, in this case, can be

construed to mean gross margin. Of the 25 questionnaires sent out, 12 were returned; 2 of the responses were rejected because of incompleteness. The questionnaire established a base project; twin 3,000-lineal-feet tunnels from a common work shaft through standing soil, primary liners of segmented steel, and the drive assumed through free air with wrap-up insurance provided by the Owner. The contractor's labor costs were assumed to be 50 percent of his total costs before contingency and profit.

7.3 ANALYSIS AND FINDINGS

The questionnaire asked each contractor to evaluate the relative contribution of each of the eleven factors to the contingency he would apply to his estimate under the best and worst circumstances associated with each factor. He was also asked to express, as a percentage of his base labor package, the total contingency and total profit that would be included in his bid price under the best and worst circumstances. It should be noted that the best and worst cases are unlikely to occur but were included here as upper and lower boundaries.

Each respondent was asked to add to the list of factors if he chose to do so; two did.

As expected, the responses showed a wide range of variation. Part of the variation is obviously attributable to differing interpretations of the questions.

Table 7-1 illustrates the spread in responses to the questions regarding contingency and profit amounts. The median value is that for which half the responses are lower or higher. From the contractor's point of view, in the worst case, where the majority of risks must be shouldered, contingency could be an amount equal to his total labor bill.

As classically interpreted, potential profits should increase as the contractor's risk increases. This is illustrated in Figure 7-1 where contingency is plotted on the horizontal scale and contingency and profit on the vertical. The contingency figures from the questionnaires represent the contractor's evaluation of relative uncertainty.

The "best" and "worst" case responses were analyzed by arranging them into frequency distributions. For the best case, the 10% to 90% frequency spread covered the range of 0% to 24% contingency; for the worst case, the 10% to 90% spread covered 19% to 96% contingency. As shown in Figure 7-1, there is a small overlap in what is considered best and worst. In fact, the graph could be interpreted as a continuum of responses representing profit and contingency as a function of the contractor's uncertainty (contingency).

The center curve (in the two fan-shaped projections) is bounded by an upper and lower limit, and this range of uncertainty contains the area into which approximately 70 percent of responses would be expected to fall.

When the contingency is removed from the Profit and Contingency, it can be seen that, in both the expected values of the best and worst cases, profit reaches a maximum and then decreases; in the best case, it is at approximately 10 percent contingency, and, in the worst case, it is at approximately 70 percent contingency. It could be surmised that the profit percentage represents the contractor's <u>minimum expected profits</u> and the contingency plus profit percentages his <u>maximum expected profit</u>.

No inferences should be drawn concerning the justification of these maximum profit levels. It only indicates that owners can significantly reduce tunneling costs by minimizing the monetary risks to be assumed by the contractor and thereby reducing the applied contingencies.

Table 7-1

HIGH-LOW RANGE OF RESPONSES
CONTINGENCY AND PROFIT ASSIGNED AS A PERCENT OF LABOR

	Best Case			Worst Case		
	Lowest	Median	Highest	Lowest	Median	Highest
Contingency	0	6	25	15	40	100
Profit	10	29	40	20	51	100
Profit + Contingency	10	35	65	35	91	200

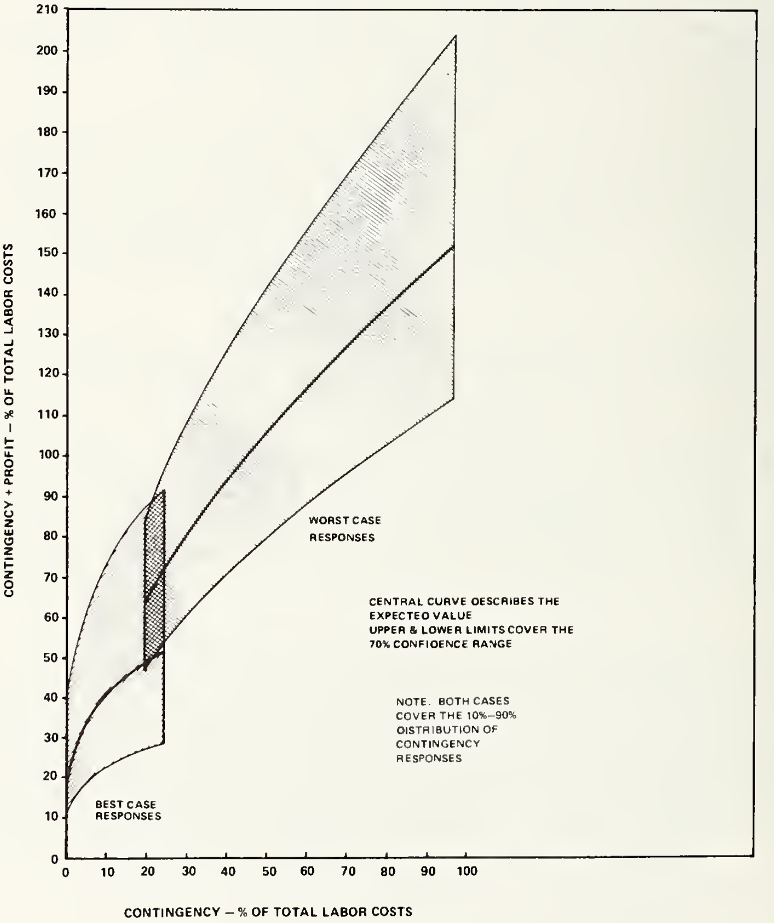


Figure 7-1. The Change in Profit Plus Contingency With Changes in Contingency

7.4 INSTITUTIONAL FACTORS IMPACT ON CONTINGENCY

The impact of the various institutional factors on contingency varied significantly among contractors; the ranges and averages are shown in Figure 7-2. Table 7-2 lists the factors by best and worst, and the median response of all contractors sampled. Availability of subsurface information in both cases is the highest contingency factor. The Owner's history of claims settlement and the labor union history account for the next largest amounts.

Figure 7-3 is a plot of the average contractor responses to the best and worst cases for each factor, in descending order, and indicates the cost differentials between the best and worst conditions.

Under usual contracting conditions, institutional factors do not generally fall completely into "best" and "worst" classes; statistically, this is a highly unlikely condition. There will more likely be a mixture of the two. In order to examine this aspect, the data for the two cases were combined and analyzed. Table 7-3 shows the result of the combination. The mean is the arithmetic average and the median divides the data into halves. The 10 percent and 90 percent points cover the statistical range into which 80 percent of the data are most likely to fall.

The spread between the mean and the median is a rough measure of the degree to which the distribution is skewed. The sign of the difference between the (Median-Mean) indicates the direction of the skewness; a negative sign means the distribution is skewed to the higher side. For instance, it is believed that it is more likely to require a greater contingency for subsurface geology information than less (Question No. 1).

Table 7-1 can now be added to recognize the variability of the data and to consider the responses as a total distribution.

Note that only the median values are added arithmetically. The 10 percent and 90 percent points are by the root-mean-square — $(\sqrt{10\%^2 + 90\%^2})$.

Table 7-2

AVERAGE UNCERTAINTY EFFECTS ON CONTINGENCY

Uncertainty Items	Percent Contributions to Contingency Best Case	Worst Case
1. The availability and analysis on subsurface geological conditions	2.5	15.7
2. Extent of Owner disclaimer with regard to subsurface conditions	0.7	5.4
3. Flexibility of engineering specifications	0.6	3.1
4. Quality of engineering specifications	0.6	3.3
5. Owner obtained rights-of-way	0.2	2.0
6. Owner obtained permits for construction and entry	0.1	1.5
7. Liability	0.6	3.8
8. Labor agreements	0.7	2.8
9. Labor union history in area	1.1	4.9
10. Owner retention period	0.3	0.4
11. Owner history of claims settlement	0.6	4.0
12. Mobilization payments 13. Scheduling problems 14. Weather 15. Proximity to water	0.4	1.7
Average Total Contingency as a Percentage of Total Labor Costs	8.4	48.6
Median Total Contingency as a Percentage of Total Labor Costs	6.0	40.0

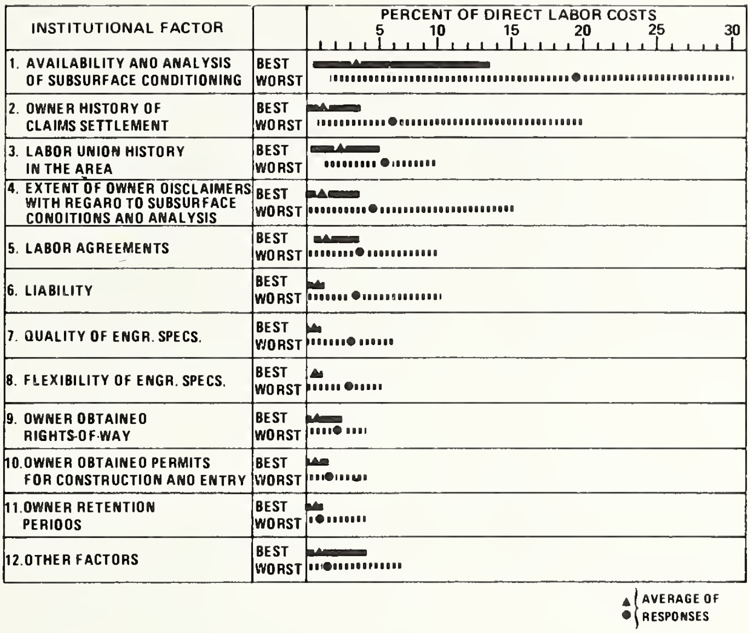


Figure 7-2. Impact on Contingency Measured as a Percentage of Direct Labor Cost

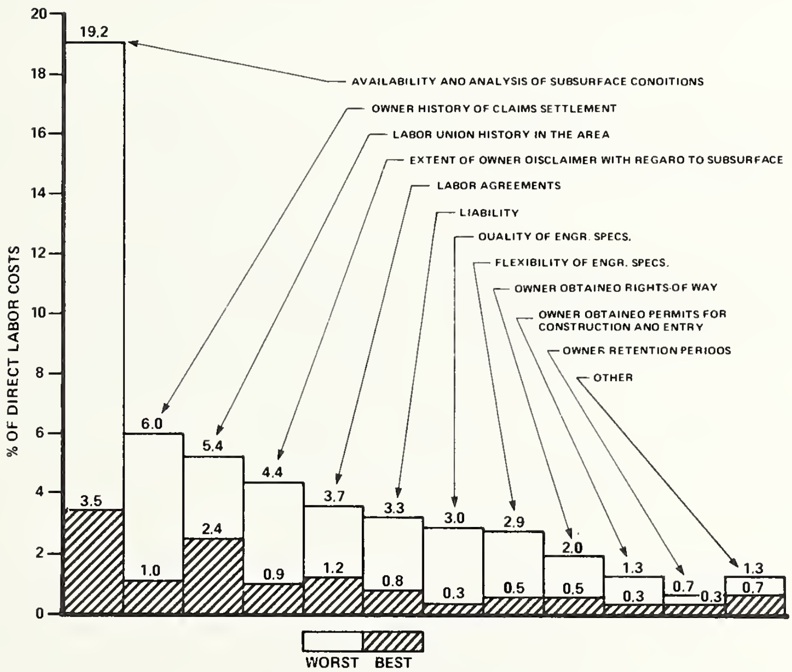


Figure 7-3. Risk Components of Contingency Under Best and Worst Cases

This again indicates to the user that extreme values are not very likely to occur.

In use, Table 7-2 would be modified by using the data from Table 7-3 (or a modification to suit the user) and Table 7-4. Medians of Table 7-3 and the contingency of Table 7-4 would be multiplied and the 10-percent and 90-percent points combined, by propagation of error, to obtain the individual contingencies as a percentage of total labor costs.

7.5 CONTINGENCY SIMULATION

To integrate the contingency information collected by the sample, three stochastic simulations were carried out, using a Monte Carlo technique; one for the average case and another for both the best and worst cases. Figure 7-4 depicts the results of this simulation. The curves representing the best and worst cases are highly unlikely and are included here for reference.

The interpretation of the lines is as follows: under the best conditions, 50 percent of the contractors will include contingency values greater than 35 percent of direct labor. Similarly, under best conditions:

- 85% will have contingency values greater than 11% of direct labor
- 70% will have contingency values greater than 18% of direct labor
- 50% will have contingency values greater than 33% of direct labor
- 30% will have contingency values greater than 51% of direct labor
- 15% will have contingency values greater than 68% of direct labor.

Similar figures can be extracted for the average and worse cases from Figure 7-4.

As a starting point, planners may find the following work sheet, Figure 7-5, useful in evaluating the impact order-of-magnitude of these institutional factors on contingency. Numerical values are based on the average values calculated from the questionnaire sample.

Table 7-3

DISTRIBUTION OF CONTINGENCY RESPONSES-
BEST AND WORST CASES COMBINED

Question Number	10%	Mean	Median (50%)	90%
1. Soils	8.5	30.9	29.0	56
2. Soils Disclaimer	-6	8.4	7.0	27.5
3. Engineering Specs.	0	6.6	5.5	15
4. Spec. Quality	0.5	7.0	4.0	20
5. Right-of-Way	0	3.1	3.0	8
6. Permits	0	2.3	1.5	6
7. Liability	0	7.8	8.0	16
8. Labor Agreements	0.5	7.2	7.5	14
9. Labor History	1	11.4	9.5	23
10. Retention	0	2.1	1.0	7
11. Claim Settlement	1	7.6	7.5	15
Mobilization	0	1.6	0	7.5

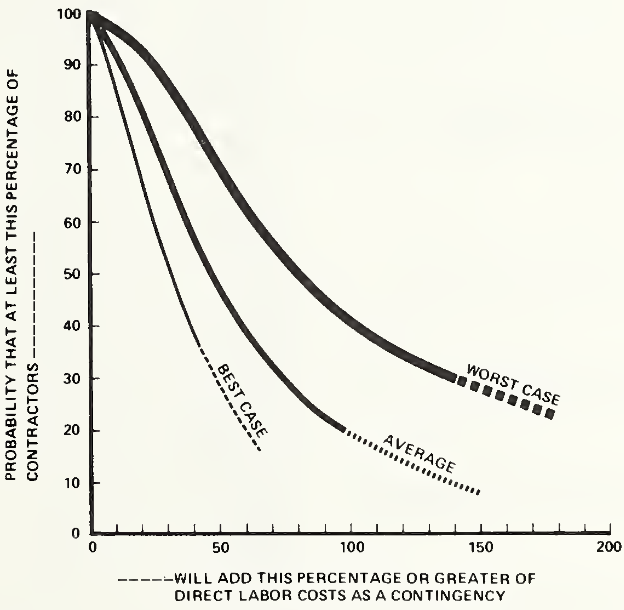


Figure 7-4. Contingency Level Probabilities

Table 7-4

CONTINGENCY AND PROFIT ASSIGNED
AS A PERCENTAGE OF DIRECT LABOR-
BEST AND WORST CASES COMBINED

	10%	Mean	Median (50%)	90%
Contingency Profit	1 17.5	28.5 40.5	21 37.5	61 71
TOTAL	17.5		58.5	93.6

Soft Ground Tunneling

IMPACT OF INSTITUTIONAL FACTORS ON COST CONTINGENCY

√ CHECK LIST

FACTORS	IF	ADD CONTINGENCY–PERCENT (%) OF DIRECT LABOR	
1. AVAILABILITY AND ANALYSIS OF SUBSURFACE GEOLOGICAL CONDITIONS	NONE MARGINAL ADEQUATE GOOD EXCELLENT	31.0 16.5 8.5 5.0 1.0	______
2. EXTENT OF OWNER DISCLAIMERS WITH REGARD TO SUBSURFACE CONDITIONS	EXTENSIVE NOMINAL FEW	8.0 2.5 0	______
3. FLEXIBILITY OF ENGINEERING SPECIFICATIONS	RIGID ADEQUATE FLEXIBLE	3.0 1.5 0.5	______
4. QUALITY OF ENGINEERING SPECIFICATIONS	MARGINAL SATISFACTORY EXCELLENT	3.0 1.5 0	______
5. OWNER OBTAINED RIGHTS-OF-WAY, ENTRY PERMITS AND CONSTRUCTION PERMITS	NONE MAJOR ONES ALL	5.5 1.5 0	______
6. LIABILITY	EXTENSIVE NOMINAL MINIMAL	5.5 2.5 0	______
7. SYSTEM WIDE LABOR AGREEMENTS	NO YES	7.0 0.5	
8. LABOR UNION HISTORY IN THE AREA	POOR MARGINAL AVERAGE GOOD EXCELLENT	7.0 5.5 4.5 1.5 1.0	______
9. OWNER RETENTION PERIOD	LONGER THAN AVERAGE AVERAGE SHORTER THAN AVERAGE	2.5 0.5 0	
10. OWNER HISTORY OF CLAIMS SETTLEMENT	POOR MARGINAL AVERAGE GOOD EXCELLENT	12.0 5.5 1.5 1.0 0.5	______
11. OTHER FACTORS			

Figure 7-5. Impact of Institutional Factors on Cost Contingency

7.6 AREA PRODUCTIVITY

The concept that productivity of skilled and unskilled craft workers varies in different geographical areas of the U.S. is generally accepted as a subjective variable. The quantification of this subjectivity is another matter and, at the present stage of knowledge, is not well established.

From proprietary sources, it is estimated, based on a value of 1.0 for the West Coast, that manhour requirements for other areas of the U.S. would have multipliers of

1.1 for the Midwest

1.15 for the East Coast (excluding New York City) and Southeast

1.2 for the Gulf Coast

based on 1972 data.

In general, the multiplier is skewed to the high side (less productive) rather than the low side. When a range of values is to be considered, the expected value +0.5, -0.3 can be considered a range into which, by chance, 20 percent of the productivity values will fall; e.g.

For the East Coast: 1.15 + 0.5 = 1.65
1.15 - 0.3 = 0.85

7.7 TUNNELING QUESTIONNAIRE

As explained earlier in this section, data had to be gathered by direct contact with major contractors, since usual breakdowns of bid figures did not provide adequate insight into the built-up estimates for our purposes. The following letter was dispatched to some 25 tunneling specialists late in December 1976.

"We are working on a D.O.T. study evaluating the cost of soft ground tunneling.

"This report is being prepared by Bechtel Corporation and basically has involved gathering statistical data from job reports in North America. The information gathered to date shows a good correlation at the direct cost level when adjusted for regional variations.

"In the areas of contingency and profit, we would like your assistance and have included a questionnaire that we hope you will take the time to fill out.

"The questionnaire is being sent to twenty-five men in the tunneling business and your response will be anonymous and tabulated to develop ranges for contingency and profit.

"The format is laid out in such a way as to reflect the extra cost of construction if the contractor is saddled with the unknown and owner-engineer has put the burden of solving problems on the contractor.

"Please respond to both cases "best" and "worst." The "best" condition would be ideal from the contractor's standpoint; for example, no disclaimer by owner-engineer regarding data and evaluation of subsurface conditions, job labor agreement, etc. The "worst" case would be your opinion of the opposite of "ideal."

"In your evaluation you will have to make assumptions based on your experience with soft ground tunneling projects but consider the basic project as:

A. 2 - 3000 LF tunnel from a common work shaft. Ground tends to stand up as steel liners are extruded from the tail of the shield.

B. Compressed air is not required and the contractor is covered by owners wrap-up insurance.

C. The contractor's labor package is equal to 50% of the total cost without contingency and profit.

"Thank you for your time on this questionnaire and we will send you a summary of the results."

Contingency Areas

Working with the job conditions described, how would the "Risk Components" tabulated below change when considering the "best" and "worst" cases.

Contribution of Risk Items to Contingency	% Contribution "Best"	% Contribution "Worst"
. The availability and analysis on subsurface geological conditions		
. Extent of owner disclaimer with regard to subsurface conditions.		
. Flexibility of engineering specifications		
. Quality of engineering specifications		
. Owner obtained right-of-way		
. Owner obtained permits for construction and entry		
. Liability		
. Labor agreements		
. Labor union history in area		
. Owner retention period		
. Owner history of claim settlement		
. Etc.		
. Etc.		
. Etc.		
Total Contingency	100%	100%

Contingency Values

Working under the above two case conditions how would the percent of contingency vary.

	"Best"	"Worst"
As % of total labor		
As % of total cost		

Profit

A. Working under the above two case conditions and assuming good confidence in estimate cost and contingency value, how would the percent of profit vary.

	"Best"	"Worst"
As % of total labor	____________	____________
As % of total cost	____________	____________

B. Same as A. with additional conditions noted.

	"Best"	"Worst"
5 or more bidders		
As % of total labor	____________	____________
As % of total cost	____________	____________
	____________	____________
3 bidders		
As % of total labor	____________	____________
As % of total cost	____________	____________

C. Modify contracting method to target estimate with 10% fixed fee plus 25% sharing in profit or losses based on target estimate.

	"Best"	"Worst"
As % of total labor	____________	____________
As % of total cost	____________	____________

7.8 CONCLUSION

The above data processing has been discussed with a degree of precision probably not supported by the accuracy of the data. The purpose was to indicate the statistical procedures involved. It is a first step in the reduction of uncertainty concerning institutional factors and can be used as a reflection of the concern of ten tunneling contractors.

More contractors should be concerned and contribute to reducing such uncertainty to the level of risk by contributing their subjective (and quantitative, if available) values to increase the discipline's total knowledge. It does seem unfortunate that a much higher degree of accuracy can be achieved in estimating tunneling labor and total costs, only to have this accuracy destroyed by the present high degree of uncertainty of institutional effects.

8. RECOMMENDATIONS

8.1 FUTURE DATA COLLECTION

Rapid Transit tunneling data generally have not been summarized into formats whereby the data could be used for future estimating. Reports, as such, have been in terms of funds expended. Because of the rapid rates of inflation during the last ten years, between and during tunnel construction, the extrapolation of past to future costs is deemed infeasible; there is no one inflation index that can be applied to all the resources used during construction.

In order to use past data, the actual resources consumed — manhours, equipment, and bulk materials — must be known so that current costs and expected escalation factors can be applied at the time new construction is contemplated to estimate the total cost of a finished tunnel.

Based on the above concept and in conformation with the study contract, the following are recommended as minimum information requirements to be reported on completion of future tunneling contracts subsidized by U.S. Department of Transportation funds.

8.1.1 Economic Factors in Tunnel Construction/Case History Data

The format is shown (filled out) in Appendix A-1. Sheets 1 through 5 summarize all but the weekly progress. The unnumbered pages are for weekly progress summaries and average soil characteristics.

The latter breakdown is not displayed. The characteristics used in this study resulted from the descriptions found in the tunneling logs. Better

descriptions can and should be developed by soils engineers — but must be compatible with the capability of the face crew foreman to quickly recognize and log. It must not be time-consuming, as his primary responsibility is the safe advancement of the tunnel face.

8.1.2 Ring and Face Log (Figure 8-1)

The weekly summary of tunnel progress is composed of Ring and Face Log data. The latter should contain sufficient information so that only clerical assistance is needed for compilation.

A suggested set of face description criteria are included that are mutually exclusive and in combination will give an adequate picture of the advancing face. The BART log sheet contained data for two rings per sheet, and the WMATA log had one ring per sheet.

8.2 ADDITIONAL STUDIES

The results reported upon here are based on tunnels whose data appeared to be quickly available. There may be data errors because there was not sufficient time to verify certain reported information that, upon study, raised questions of correctness. These data should be verified or corrected.

Not enough different soil types were included. Glacial till soils, to evaluate the effect of cobbles and boulders, need inclusion. The Toronto subway and Edmonton sewer systems have those soil characteristics and one or more tunnels should be added to the data deck.

All the collected data were not studied and should be analyzed to determine:

- Equipment types most applicable to expected tunneling conditions and lengths.

RING & FACE LOG

Tunnel #________ (OB/IB), Contract #________, Contractor________, Walker:________, Shifter:________
Date:____/____/19____, Shift:__________, Tunnel Pressure:__________ psig, Weather:__________

Ring #__________, Station @ Start of Shove:____ ____ +__________. Time @ Start of Shove:__________
(24 hr clock) Time @ End of Shove:__________
No. Muck Vehicles Filled:________ Minutes:__________

Ring #__________ Expanded, Diameter After Expansion:__________, Time @ Start of Ring Erection:__________
Expansion Time:____ ______, Expander Press:__________psig, Time @ End of Ring Erection:__________
Minutes:__________

ESTIMATED SOIL FACE COMPOSITION

Silt:________%, Clay:________%, Sand:________%,
Gravel:__%, Rocks & Boulders:__%, Peat & Trash:__%.

ESTIMATED FACE CONDITION (SCALE 0–1.0)

Running:__________, Moderately Stable:__________,
Stable:______________, Hard: ______________,
Breasting:____ Yes____, No____.

ESTIMATED WATER CONDITIONS

Dry:_____(0), Damp:_____(.2), Slight Flow:_____(.5)
Operating w/Pumps:_____(.75), Flooded Out:_____(1.)

Shove Jacks, Show jacking pressures on profile.

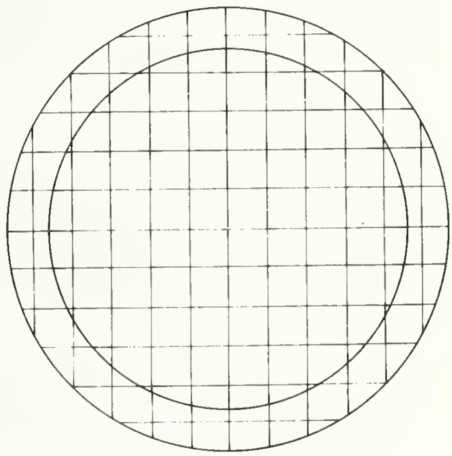
TARGET POSITIONS AFTER SHOVE:

	Left	Right	Hi	Lo
Front	____	____	____	____
Rear	____	____	____	____

Grout Used:______________(gravel/cement)

FACE PROFILE BEFORE SHOVE

(Sketch Soil Characteristics & Location)



(Note: Outside circle = 100 units. Each square = 1% of total area)

Roll of Shield:______________

SHUTDOWNS

Time @ Beginning:________, Continuing (ck)________, Time @ End:__________, Reason:__________
Time @ Beginning:________, Continuing (ck)________, Time @ End:__________, Reason:__________
Time @ Beginning:________, Continuing (ck)________, Time @ End:__________, Reason:__________

Slowdowns, Reasons For: ______________________________

Other Comments: ______________________________

(Note crew size on first ring log of shift)

Figure 8-1. Ring and Face Log

- Crew staffing as a function of equipment to be used and expected tunneling conditions.

Bulk material requirements must be added to the system.

Although a beginning was made in estimating the effects of institutional factors, it was only a beginning. Mailed-out questionnaires are notorious for their poor responses. Because of the gross effects these factors have on costs — which far overshadow the quantitized tunneling effort — a more detailed study needs to be made. Contractors should be interviewed because the response percentage will be increased. And more factors will be included.

Our questionnaire only went to transit tunneling contractors. All tunneling contractors, including those for large-diameter sewers, for both soft ground and hard rock should be included. The questionnaire should be expanded.

Equipment maintenance and depreciation were not readily found, but need to be included.

The derived predicting equations should be analyzed for stability of the derived coefficients. Ridge analysis[9] is one method of modifying the coefficients to achieved satisfactory stability. It was precluded in this study by the restraints of time and resources.

8.3 RISK MODEL

All the above data, including the results of the study to date together with their variances, will be useless unless they are combined in a simulation model. Not only useless, but incomprehensible.

A risk analysis model must be written to facilitate the complete use of the data [10] and allow the decision maker to make a rational judgment about the economics of the project.

9. GUIDELINES

Two forms are suggested for future data acquisition. Section 3.1.1 lists the data used in this study. The data are keypunched in a 7F10.5 format on the card deck forwarded separately as part of this report.

The key document on the advance rate is the Ring and Face Log. Daily perusal of the shift's logs should be made by supervisory personnel to ensure accuracy and completion. Weekly averaging of the data is highly recommended so that questions on omissions and errors can be corrected before memories of events are forgotten. To save time, the weekly averages should be posted directly to keypunch sheets. The forms used are shown in Appendix A-6.

In the following, consider each variable on the keypunch form of Appendix A-6 as XI, X2, ----, X42.

The intercept and learning curve exponents are estimated first:

- Plot X4/X2 (hr/ft) vs X3-0.5*X2(Σft) on log-log paper.
- Remove obvious outliers from the immediate analysis (they will be used later).
- Regress $Ln(hr/ft) = f\left[Ln(\Sigma ft)\right]$.

The estimated values are punched into the data cards as X38 and X42.

Analysis of the tunnel RoA or a larger matrix composed of many tunnels is made by —

- Obtaining correlation coefficients between all input variables,

- Eliminating variables that have no logical (engineering) basis for being included in the analysis,

- Eliminating variables having correlation coefficients greater than $\pm$ 0.9 (the analyst may have his own level for elimination). In such cases, one variable is probably adequately explaining the variation in the other,

- Eliminating variables that appear only a few times. These variables may induce an exaggerated effect. If the variable is considered to be logically important, it may be useful to examine its effect in a smaller matrix of data with other variable characteristics of a similar nature.

Based on the inter-correlation coefficients of independent variables left for consideration, new dummy variables may be constructed (see section 6.0) that will increase the explanatory value of the predicting equation.

The effect of the learning curve and intercept have been previously determined. Only the multiplier effects of soils, equipment types, and their breakdowns are to be found. The dependent variable (see Figure 5-7) is calculated by

$$Y = \frac{X4/X2}{X38* (X3-0.5*X2)**X42} = \frac{hr/ft}{I* (\Sigma ft)^E}$$

The Ln Y is regressed against the logs of the independent variables and their dummys.

A best equation can now be selected.

The same basic procedure is followed for estimating the other prediction equations.

The best form for the downtime predictions is not yet finalized. Figure 6-2 may provide a satisfactory basis for analysis.

Figure 5-1 shows the system calculations for estimating the tunnel construction cost. As a final step, the equations are combined, together with costs and derived (as well as subjective) variabilities into a Monte Carlo simulation to estimate the expected cost and its distribution. This is known as risk analysis[10]. The contractor can then bid, based on his "feel" for the degree of confidence he believes is justified. The advantage of risk analysis is that it quantifies a large portion of the unknown.

Appendix A

PHYSICAL DATA

Data included in this appendix are:

A-1	Characteristics of tunnels and equipment
A-2	Average weekly progress
A-3	Rate of advance calculations
A-4	Calculation of downtime hours
A-5	Total estimated shift hours and percentage of error
A-6	Keypunch forms

Appendix A-1

A partial record of the physical characteristics of the individual tunnel and equipment used in several tunnels.

Although it is expected that the complete history is available in the historical record files, complete information could not be located in the time available for the searches.

It is recommended that this or a similar form be used to record the pertinent history of future tunneling operations.

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY OATA

A DESCRIPTION

1. PROJECT NAME 24th to Randall St.	NUMBER 1M0031
2. LOCATION San Francisco, California	
3 OWNER Bay Area Rapid Transit District	ENGINEER PBTB
4. CONTRACTOR Morrison-Knudsen Co.,Inc., Brown+Root Inc, Perini Corp(JV)	
5. OATES: START May 27, 1967	COMPLETE November 17, 1969

6 PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

Includes construction of subway line tunnels of approximately 4525 LF of MR line and 4500 LF of ML line, placing tunnel invert and walkway concrete; construction of a vent shaft and switching station and a pumping station; mechanical and electrical work; and installation of segmented steel tunnel rings, fans and pumps.

7. OWNER FURNISHED MATERIAL ANO EQUIPMENT LIST

Segmented steel rings, pumping station equipment and ventilation equipment.

8. OTHER OWNER SUPPLIED COST ITEMS (e g INSURANCE)

Right-of-ways

B. OESIGN INFORMATION SHEET 1 OF

1. PLAN AND PROFILE ATTACHED	YES	NO
2. TYPICAL SECTION DRAWING ATTACHEO	YES	NO
3. TEMPORARY LININGS OETAILS ATTACHED	YES	NO
4. PERMANENT LININGS OETAILS ATTACHEO	YES	NO
5. GEOLOGICAL PROFILE ATTACHEO:	YES	NO

6. VERBAL DESCRIPTION OF SOIL CONOITIONS

Soil consists of sandy clay ranging from medium to very dense; gray clay with some sand; red, brown and gray clay, all with density of medium to very dense, plus two areas that had a large amount of fractured rock. The Contractor ran into some fractured churt.

7. OEWATERING PLAN ATTACHED YES NO

8. GROUNO WATER CONDITIONS DESCRIPTION

Underground water table showed to be consistent throughout the right-of-way so Contractor dewatered the entire tunnel length making it possible to drive only 1/3 of tunnel length in compressed air.

9 SITE PREPARATION & RESTORATION DESCRIPTION

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY OATA

B. OESIGN INFORMATION (CONTINUEO)

10. UNOERPINNING DESCRIPTION

Underpinning of the Sears store at Mission and Army streets was accomplished by drilling caisson holes to extend about 10 ft. below the invert of the future tunnel. Bentonite slurry was used to keep the holes open. Then reinforcing was lowered into the caisson holes and tremie concrete was placed in the slurry-filled holes. New concrete pile caps were constructed to support the existing pile caps and the building.

11. UTILITIES. OESCRIPTION

Relocation is minimal. Electric, gas and water lines on the east side of Mission St. were relocated around the end of the access shaft. All other utilities supported in place.

C. CONSTRUCTION METHODS SHEET 2 OF

1. FREE AIR 2/3 of tunnel		LENGTH (FT) 6018
2 COMPRESSEO AIR 1/3 of tunnel		LENGTH (FT) 3007
PSIG MIN 0	PSIG MAX 14	PSIG WTO AVG. 3.233

3. OESCRIPTIONS

TUNNEL EXCAVATION

Excavation was with a 17.92' shield with 2 Full Breasting Wheel-Type Mining machines and a conveyor system consisting of skiphoist and conveyor extending 165 LF

PRIMARY LINING

Composed of 30-inch wide, 17.5-ft. outside diameter circular welded steel rings, each consisting of 6 larger segments and one small key segment.

FINAL LINING

Appendix A-1. Characteristics of Tunnels and Equipment

D. MAJOR EQUIPMENT UTILIZED

SHEET 3 OF

1. CUTTING AND EXCAVATING

MAKE	Mining Equipment Manufacturing Corp.
MODEL	
TYPE	ROTATING WHEEL ✓ / OSCILLATING ARMS / DIGGING ARM
OTHER (SPECIFY)	
CONNECTED HORSE POWER	225
NO. USED	2

2. SHIELD

OUTSIDE DIA.	17.92 Ft	LENGTH	12 ft. 5 in.
NO. OF JACKS	Shove 19, Double Shove 5	THRUST FORCE (TONS) EACH JACK	115
NO. OF JACKING MOTORS	4		
HORSE POWER EA. JACKING MOTOR	50		
NO. SHIELDS USED	1		

3. MUCKING EQUIPMENT (UNDERGROUND)

TYPE	Conveyor and skiphoist		
CONVEYOR LENGTH (FT.)	165	CAPACITY	5,400,000 lbs.
RAIL CARS NO.	5	CAPACITY (T)	7 cy
RUBBER TIRE VEHICLE NO		CAPACITY (T)	
COMBINATION (SPECIFY)			

4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)

A skip hoist extending from a sump 15 ft. below the base slab to an elevation of 40 ft. above the street surface was erected. An electric motor-powered winch at the top of the structure was used to hoist a ten-cubic yard skip from the sump to a conveyor attached to the hoist structure 25-ft. above the street surface. The skip was lifted up the hoist and tipped and emptied onto the conveyor upon reaching it.

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.

GROUTING

DESCRIPTION	CAPACITY	NO.
Moyno Grout Pump - Rotor-Stator pumping type		2
Kwik-Mix Cyclo Grout Mixer	1/2 yd.	1
Grout cars	1/2 cyd.	1

CONCRETE INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.
P&C Whiteman Concrete pump - 90 hp	14-1/2 cuft.	2

6. VENTING, PUMPING, COMPRESSION, EQUIPMENT

DESCRIPTION	CAPACITY	NO
Low Air Compressors - 300 Hp ea.	11,000 total CFS @ 50 PSI	5

7. OTHER (Specify)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

E. QUANTITIES (NOT INCL. ACCESS SHAFT)

SHEET 4 OF

1. TUNNEL (IF MULTIPLE, SHOW FOR EACH)

LENGTH	Both tunnels - 9000 LF
INSIDE DIA.	16'-6"
OD	17'-6"
CONFIGURATION	Circular
NO. CROSS OVERS, IF MULTIPLE (EA)	
TOTAL EXCAVATION (CY)	80,800
TUNNEL PRESSURE RANGE	12 PSI - 14 PSI

2. GROUTING (CY)

	EST	ACTUAL
BEHIND TEMP. LINING		4800
CONSOLIDATION (FACE)		
PREGROUTING		

3. PRIMARY LINING

DESCRIPTION	QUANTITY
Liner Segments, steel	3612

4. SECONDARY LINING

TYPE: Type II cement

NO. LINERS IF PREFAB OR PRECAST (EA):

QUANTITIES IF CAST IN PLACE

DESCRIPTION	QUANTITY
CONCRETE	(CY)
REINFORCING	(TONS)
FORMING	(S F)

6. INVERT (AND WALKWAYS), ARCH

DESCRIPTION	QUANTITY
CONCRETE - Invert, Type II	6539 (CY)
REBAR	(TONS)
FORMS - 8 ft long Steel	(S F)
STRUC STEEL	(TONS)
concrete - Walkways	72 cy

7. MAJOR UNDERPINNINGS

DESCRIPTION	AREA (S.F.)
TOTAL	

8. AIRLOCK SYSTEM (IF USED)

MAN LOCKS		
NUMBER	2	(EA)
LENGTH	40	(FT)
DIAMETER	6	(FT)
MUD LOCK		
NUMBER	2	(EA)
LENGTH	140	(FT)
DIAMETER	9	(FT)
BULK HEAD DESIGN	50	PSIG

9. APPURTENANT STRUCTURES

VENT AND FAN SHAFTS

CONSTRUCTION METHOD	Soldier Beam and Lagging
WIDTH	94 (FT)
BREADTH	27 FT
DEPTH	50 FT
WALL THICKNESS	3 ft
EXCAVATION QUANTITIES	4900 (CY)
CONCRETE QUANTITIES	2200 (CY)

PUMPING STATIONS

CONSTRUCTION METHOD	Sheet Piles and Internal Support
CONFIGURATION	Circular Manhole Type Struct.
DEPTH	53.5 (FT)
DIAMETER	8-16 (FT)
EXCAVATION QUANTITIES	410 (CY)
CONCRETE QUANTITIES	130

OTHER APPURTENANCES (SPECIFY)

DESCRIPTION	EXCAV (CY)	CONCRETE (CY)
24th Street Construction Shaft	11,706	—

10. SITE PREPARATION & RESTORATION

DESCRIPTION	TYPE	AREA (S.F.)
CLEAR & GRUB		
REMOVAL		
RESTORATION		

Appendix A.1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F TYPICAL CREW SIZE AND UTILIZATION (1)

SHEET 5 OF ____

1. CREW – Heading – Free Air
SHIFTS / DAY 3 HOURS / SHIFT 8

WORKING DESIGNATION	1ST SHIFT	2nd SHIFT	3rd SHIFT
Shifter	1	1	1
Heading Engr.	1	1	1
Mole Operator	1	1	1
Mole Mechanic	2	2	2
Iron Movers	2	2	2
Iron Workers	4	4	4
Hog Rod and Bracket Men	2	2	2
Grout Pump Oper.	1	1	1
Grout Men	2	2	2
Locomotive Oper.	1	1	1
Brakeman	1	1	1
Electrician	1/2	1/2	1/2
	(one man for two headings)		
TOTAL	18-1/2	18-1/2	18 1/2

2. CREW – Heading - Compressed Air
SHIFTS / DAY 4 HOURS / SHIFT 6

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT	4TH SHIFT
Heading Engr.	1	1	1	1
Shifter	1	1	1	1
Mole Lead Mechanic	1	1	1	1
Mechanic	1	1	1	1
Mole Operator	1	1	1	1
Iron Worker	4	4	4	4
Iron Mover	2	2	2	2
Hog Rod and Bracket Man	2	2	2	2
Grout Pump Operator	1	1	1	1
Grout Man	2	2	2	2
Locomotive Oper.	1	1	1	1
Brakeman	1	1	1	1
Electrician	1/2	1/2	1/2	1/2
Manlock Operator	1	1	1	1
Outside Mucklock Operator	1	1	1	1
Inside Mucklock Operator	1	1	1	1
TOTAL	21-1/2	21-1/2	21-1/2	21-1/2

3. CREW – Top Side
SHIFTS / DAY 3 HOURS / SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
General Supt.	1	–	–
Walker	1	1	1
Surveyor	3	–	–
Mechanic Foreman	1	1	1
Mechanic	4	1	1
Electrical Foreman	1	–	–
Electrician	3	1	1
Top Laborer	2	2	2
Bridge Crane Operator	1	1	1
Lube Engineer (Oiler)	1	–	–
Gen'l Operator	1	1	1
Compressor Opr.	1	1	1
Change House Attendant	1	1	1
Warehouseman	2	–	–
TOTAL	23	10	10

4. CREW – Invert Concrete
SHIFTS / DAY 1 HOURS / SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Foreman	1		
Winch Operator	1		
Vibrator Men	2		
Cement Finishers	3		
Rebar Man	1		
Slick Line-Laborers	2		
Final Clean-up-Laborers	4		
Pump-Laborer	1		
Operator at Pump	1		
TOTAL	16		
5. Crew – Prep. and Form Setting			
SHIFTS/DAY 1	HRS/SHIFT 8		
Foreman	1		
Laborers	18		
Laborers for Walkway	9		
TOTAL	28		

(1) NOTE CATEGORY OF CREWS (HEADING, SUPPORT SURFACE SHAFT ETC.) REPORT AS LOGGED

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

A DESCRIPTION

1 PROJECT NAME Berkeley-North	NUMBER 1R0053
2 LOCATION Berkeley, California	
3 OWNER Bay Area Rapid Transit District	ENGINEER PBTB
4 CONTRACTOR Shea-Mocco	
5 DATES START 11/28/66	COMPLETE 5/5/68

6 PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

Approximately 1,475 feet of curved twin subway line tunnels, Approximately 2700 feet of cut-and-cover twin box subway structure, including installation of mechanical and electrical equipment and the relocation and construction of utilities.

7 OWNER FURNISHED MATERIAL AND EQUIPMENT LIST

Owner furnished tunnel lining of 30 inches wide, 18 ft outside diameter circular welded steel rings, pumping

8 OTHER OWNER SUPPLIED COST ITEMS (e.g. INSURANCE)

B DESIGN INFORMATION

SHEET 1 OF ____

1 PLAN AND PROFILE ATTACHED	YES	NO
2 TYPICAL SECTION DRAWING ATTACHED	YES	NO
3 TEMPORARY LININGS DETAILS ATTACHED	YES	NO
4 PERMANENT LININGS DETAILS ATTACHED	YES	NO
5 GEOLOGICAL PROFILE ATTACHED	YES	NO

6 VERBAL DESCRIPTION OF SOIL CONDITIONS Interfingering lenses of clayey gravel, sandy and silty clays, and clayey or silty sands. Layers are of irregular thickness and grade into each other within short distances, both horizontally and vertically. Olive gray sandstone was encountered in the invert of the tunnel, weathered to a light brown at the upper soil contact and underlain by a dark olive green shale.

7 DEWATERING PLAN ATTACHED YES NO

8 GROUND WATER CONDITIONS DESCRIPTION

Before dewatering, the water level was 10 ft. above the top of the future structure. No dewatering system installed outside excavation. Submersible Sweck pump was placed in tunnel invert at heading and was in all cases sufficient.

9 SITE PREPARATION & RESTORATION DESCRIPTION

Approximately 150-ft wide area above future cut-and-cover area was available as a work area. Owner provided a lot about 55 ft wide and 280 ft long to contractor for use during construction. Tempora...

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

B DESIGN INFORMATION (CONTINUED)

work area on the adjacent contract (R0057) was used
: a saw yard until Contract R0057 was bid, mid-1968.

10. UNDERPINNING DESCRIPTION

11. UTILITIES DESCRIPTION

C. CONSTRUCTION METHODS

SHEET 2 OF

1. FREE AIR: LENGTH (FT) 4,175
2. COMPRESSED AIR: not used LENGTH (FT) —
PSIG MIN — PSIG MAX — PSIG WTD AVG. —

3. DESCRIPTIONS

TUNNEL EXCAVATION

Excavation was with an 18 ft 8½ in. shield. A rubber-tired truck transported the muck from the heading to the Temporary Access Shaft. After the last mucking run, the mucker brought in a set of ring segments for the next ring. The tunnel was hand-mined.

PRIMARY LINING

30" wide, 18.0 ft outside diameter circular welded steel rings each consisting of 6 larger segments and one small key segment.

FINAL LINING

Invert was concrete with a 1-½ in. maximum aggregate size. Walkway concrete used a 1-in. maximum aggregate size.

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

D. MAJOR EQUIPMENT UTILIZED

1. CUTTING AND EXCAVATING
MAKE
MODEL
TYPE: ROTATING WHEEL / OSCILLATING ARMS / DIGGING ARM
OTHER (SPECIFY) Manual Digging
CONNECTED HORSE POWER
NO USED

2. SHIELD
OUTSIDE DIA. 18 ft 8½ in. LENGTH Top 13'6" – Bottom 11'6"
NO. OF JACKS 28 THRUST FORCE (TONS) EACH JACK 100/50 NO. OF JACKING MOTORS 4
HORSE POWER EA. JACKING MOTOR 20 Hp
NO. SHIELDS USED 1

3. MUCKING EQUIPMENT (UNDERGROUND)
TYPE: Diesel Powered Mucker
CONVEYOR LENGTH (FT.) CAPACITY (T)
RAIL CARS NO. CAPACITY (T)
RUBBER TIRE VEHICLE NO. L8L 714 Model CAPACITY 22,000 Lbs
COMBINATION (SPECIFY)

4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)

SHEET 3 OF

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.
Gardner Denver Air Hoist - Model 86-2V-20L		
Impact Wrenches		

GROUTING

DESCRIPTION	CAPACITY	NO.
Moyno grout pumps	22 Hp	2
Grout Plant for Cement		
Grout Mixer (First tunnel only), 1000 West plaster mortar mixer with air motor		

CONCRETE INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.
Beltcrete Swinger conveyor system		

6. VENTING, PUMPING, COMPRESSION, EQUIPMENT

DESCRIPTION	CAPACITY	NO.
Joy Air Fan for Ventilation	50 Hp	
Gardner Denver compressor	125 Hp / 500 cfm	2

7 OTHER (Specify)

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

E. QUANTITIES (NOT INCL. ACCESS SHAFT)

SHEET 4 OF ___

1. TUNNEL (IF MULTIPLE, SHOW FOR EACH)			
LENGTH	2,903		FT
INSIDE D RR: 17'-0"	RL: 17'-0"		
CONFIGURATION	circular		
NO. CROSS OVERS, IF MULTIPLE			EA.
TOTAL EXCAVATION			CY
TUNNEL PRESSURE RANGE	0	PSI	0 PSI

2. GROUTING (CY)	EST	ACTUAL
BEHIND TEMP. LINING		
CONSOLIDATION (FACE)		
PREGROUTING		

3. PRIMARY LINING

DESCRIPTION	QUANTITY
Welded Steel Rings - Circular	580

4. FINAL LINING

TYPE	Concrete	
NO. LINERS IF PREFAB OR PRECAST		EA
QUANTITIES IF CAST-IN-PLACE		

DESCRIPTION	QUANTITY
CONCRETE	(CY)
REINFORCING	(TONS)
FORMING	(S.F.)

6. INVERT (AND WALKWAYS), ARCH

DESCRIPTION	QUANTITY
CONCRETE - Invert	RR: 1196 RL: 1080 (CY)
REBAR	(TONS)
FORMS	(S.F.)
STRUC. STEEL	(TONS)
Walkways RR: 299 cy	RL: 285 cy
Cross-Passage	74 cy

7. MAJOR UNDERPINNINGS

DESCRIPTION	AREA (S.F.)
TOTAL	

8. AIRLOCK SYSTEM (IF USED)

MAN LOCKS	
NUMBER	(EA)
LENGTH	(FT)
DIAMETER	(FT)
MUD LOCK	
NUMBER	(EA)
LENGTH	(FT)
DIAMETER	(FT)
BULK HEAD DESIGN	PSIG

9. APPURTENANT STRUCTURES

TEMPORARY ACCESS SHAFT

CONSTRUCTION METHOD: Soldier pile and Lagging with tie bars for lateral support for piles.

WIDTH 45 (FT)	BREADTH 150 FT	DEPTH FT
WALL THICKNESS		
EXCAVATION QUANTITIES		(CY)
CONCRETE QUANTITIES		(CY)
PUMPING STATIONS		
CONSTRUCTION METHOD		
CONFIGURATION		
DEPTH (FT)	DIAMETER (FT)	
EXCAVATION QUANTITIES		(CY)
CONCRETE QUANTITIES		

OTHER APPURTENANCES (SPECIFY)

DESCRIPTION	EXCAV (CY)	CONCRETE (CY)

10. SITE PREPARATION & RESTORATION

DESCRIPTION	TYPE	AREA (S.F.)
CLEAR & GRUB		
REMOVAL		
RESTORATION		

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F. TYPICAL CREW SIZE AND UTILIZATION (1)

SHEET 5 OF ___

1. CREW - Heading Crew — SHIFTS/DAY 3 — HOURS/SHIFT = 8

WORKING DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Shift Boss	1	1	1
Surveyor	1	1	1
Shield Operator	1	1	1
Muck Operator	1	1	1
Miner	4	4	4
TOTAL	8	8	8

2. CREW - Grout Crew — SHIFTS/DAY 1 — HOURS/SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Grout Foreman	1		
Grout Man	3		
TOTAL	4		
Caulking Crew	Graveyard - 1-8 hr Shift		
Laborer			2
TOTAL			2

3. CREW - Top and Shaft Crew — SHIFTS/DAY — HOURS/SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Compressor Operator	1	1	1
Forklift Operator	1		
Laborer	1		
TOTAL	3	1	1
Carpenter Crew	1 - 8 hr Shift		
Carpenter Supt.	1		
Carpenter Foreman	1		
Carpenter	4		
TOTAL	6		

4. CREW - Cleanup Crew — SHIFTS/DAY 1 — HOURS/SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Shifter		1	
Laborer		6	
Compressor Operator		1	
Forklift Operator		1	
TOTAL		9	
Concrete Crew	1 - 8 hr Shift		
Shifter	1		
Belt Operator	1		
Swing Operator	1		
Vibrator Man	3		
Laborer	3		
Finisher	2		
TOTAL	11		

(1) NOTE: CATEGORY OF CREWS (HEADING, SUPPORT, SURFACE, SHAFT ETC.) REPORT AS LOGGED

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY OATA

A. DESCRIPTION

PROJECT NAME NEW CARROLLTON ROUTE-D-9		NUMBER	100091
LOCATION WASHINGTON, D.C.			
3. OWNER WMATA		ENGINEER JOSEPH K. KNOERLE	
4. CONTRACTOR FRUIN-COLNON			
5. OATES:	START 1-30-75	COMPLETE 3-21-75	

6. PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

735 L.F. DUAL TUNNEL W/ PORTAL

DESIGNED AS OPEN CUT- CHANGED TO TUNNEL AFTER AWARD- SAVINGS OF $520,000.00

7. OWNER FURNISHED MATERIAL AND EQUIPMENT LIST NONE

8. OTHER OWNER SUPPLIED COST ITEMS (e.g INSURANCE)

B. DESIGN INFORMATION. SHEET 1 OF

1. PLAN ANO PROFILE ATTACHEO	YES	NO
2. TYPICAL SECTION DRAWING ATTACHED:	YES	NO
3. TEMPORARY LININGS DETAILS ATTACHED:	YES	NO
4. PERMANENT LININGS DETAILS ATTACHED:	YES	NO
5. GEOLOGICAL PROFILE ATTACHEO:	YES	NO

6. VERBAL OESCRIPTION OF SOIL CONDITIONS:

MOSTLY CLAY WITH SOME CEMENTED SAND

7. OEWATERING PLAN ATTACHED YES NO

8. GROUND WATER CONDITIONS OESCRIPTION

9. SITE PREPARATIDN & RESTORATIDN DESCRIPTION

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY OATA

B. DESIGN INFORMATION (CONTINUED)

10. UNOERPINNING OESCRIPTION

UNDERPIN 22' x 23'-6" SEWER STRUCTURE

4'-6" ⌀ INTERCEPTOR SEWER

11. UTILITIES. DESCRIPTION

STANDARD UNDERSTREET UTILITIES SUPPORTED AND/OR RELOCATED - A LARGE UTILITY SAVINGS IN CONTRACT PRICE RESULTED IN CHANGING FROM OPEN CUT TO TUNNEL

C. CONSTRUCTION METHODS SHEET 2 OF

1. FREE AIR. YES	LENGTH (FT)	735-735
2. COMPRESSEO AIR:	LENGTH (FT)	
PSIG MIN	PSIG MAX	PSIG WTO AVG.

3. DESCRIPTIDNS

TUNNEL EXCAVATION

TEMPORARY LINING

RIBS & LAGGING + GROUT

FINAL LINING

15" CONCRETE

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

D. MAJOR EQUIPMENT UTILIZED

SHEET 3 OF

1. CUTTING AND EXCAVATING HAND EXCAVATION

MAKE

MODEL

TYPE: ROTATING WHEEL | OSCILLATING ARMS | DIGGING ARM

OTHER (SPECIFY)

CONNECTED HORSE POWER

NO. USED

2. SHIELD ELGOOD MAYO

OUTSIDE DIA.	18'	LENGTH	16'-6"		
NO. OF JACKS	24	THRUST FORCE (TONS) EACH JACK	75*	NO. OF JACKING MOTORS	4

HORSE POWER EA. JACKING MOTOR 20

NO. SHIELDS USED 1

3. MUCKING EQUIPMENT (UNDERGROUND)

TYPE: FRONT END LOADER

CONVEYOR LENGTH (FT.)		CAPACITY	(T)
RAIL CARS: NO		CAPACITY	(T)
RUBBER TIRE VEHICLE NO.	EIMCO 915C-LHD	CAPACITY	5CY (T)

COMBINATION (SPECIFY)

4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)

LOADER TO TUNNEL PORTAL
RELOADED ON TO TRUCK FOR DISPOSAL

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.

GROUTING

DESCRIPTION	CAPACITY	NO.

CONCRETE INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.

6. VENTING, PUMPING COMPRESSION EQUIPMENT

DESCRIPTION	CAPACITY	NO

7. OTHER (Specify)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F. TYPICAL CREW SIZE AND UTILIZATION (1)

SHEET 5 OF

1. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORKING DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
AVERAGE CREW	13	13	
TOTAL			

2. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

3. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

4. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

(1) NOTE CATEGORY OF CREWS (HEADING, SUPPORT SURFACE SHAFT ETC.) REPORT AS LOGGED

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

A. DESCRIPTION

1. PROJECT NAME Section F2A - Branch Route	NUMBER 1F0021
LOCATION Washington D.C.	
3. OWNER WMATA	ENGINEER PBQD
4. CONTRACTOR Traylor Bros. & S.M.	
5. DATES: START	COMPLETE

6. PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

8,855 LF Tunnel (Twin Bores - Inbound - Outbound)
Plus: Ventilation Structures,
Underground Electrical Substation,
Drainage Pumping Stations
Underpinning of Surface Structures

7. OWNER FURNISHED MATERIAL AND EQUIPMENT LIST

None

8. OTHER OWNER SUPPLIED COST ITEMS (e.g. INSURANCE)

B. DESIGN INFORMATION SHEET 1 OF ___

	YES	NO
1. PLAN AND PROFILE ATTACHED		✓
2. TYPICAL SECTION DRAWING ATTACHED		✓
3. TEMPORARY LININGS DETAILS ATTACHED		✓
4. PERMANENT LININGS DETAILS ATTACHED		✓
5. GEOLOGICAL PROFILE ATTACHED		

6. VERBAL DESCRIPTION OF SOIL CONDITIONS

Sand with Clay Lenses, Some Medium Stiff Clay
Sand & Gravel Layers with Some Boulders

7. DEWATERING PLAN ATTACHED YES ___ NO ✓

8. GROUND WATER CONDITIONS DESCRIPTION

9. SITE PREPARATION & RESTORATION DESCRIPTION

Replace 482 SY of Street Pavement
1075 LF - Curb & Gutter & 555 SY Sidewalk

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

B. DESIGN INFORMATION (CONTINUED)

10. UNDERPINNING DESCRIPTION

Temporary Support of 7th Street Bridge
With Grout Underpinning

Grout Underpinning - Jefferson Memorial
Junior High School

11. UTILITIES DESCRIPTION

Standard Utility Installations Buried in
Streets Above - Supported and/or Relocated
As Required

C. CONSTRUCTION METHODS SHEET 2 OF ___

1. FREE AIR. Yes		LENGTH (FT) [redacted]
2. COMPRESSED AIR		LENGTH (FT)
PSIG MIN	PSIG MAX	PSIG WTD AVG.

3. DESCRIPTIONS

TUNNEL EXCAVATION

Backhoe Excavation Thru Shield - Muck
Removed By Conveyor Belt To Rail
Mounted Muck Cars
Tunnel Grouted Thru Steel Liner
Plates

TEMPORARY LINING None

FINAL LINING Steel Liner Plates

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

D. MAJOR EQUIPMENT UTILIZED

SHEET 3 OF

1. CUTTING AND EXCAVATING

MAKE						
MODEL						
TYPE	ROTATING WHEEL		OSCILLATING ARMS		DIGGING ARM	
	OTHER (SPECIFY)					
CONNECTED HORSE POWER						
NO. USED						

2. SHIELD ROBBINS

OUTSIDE DIA.	18'-0"	LENGTH	16'-6"		
NO. OF JACKS	24	THRUST FORCE (TONS) EACH JACK	75	NO. OF JACKING MOTORS	4
HORSE POWER EA. JACKING MOTOR	20				
NO. SHIELDS USED	1				

3. MUCKING EQUIPMENT (UNDERGROUND)

TYPE	FRONT END LOADER		
CONVEYOR LENGTH	(FT.)	CAPACITY	(T)
RAIL CARS NO		CAPACITY	(T)
RUBBER TIRE VEHICLE NO	915C-4WD EIMCO	CAPACITY	5CY (T)
COMBINATION (SPECIFY)			

4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.

GROUTING

DESCRIPTION	CAPACITY	NO.

CONCRETE INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.

6. VENTING, PUMPING, COMPRESSION, EQUIPMENT

DESCRIPTION	CAPACITY	NO.

7. OTHER (Specify)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

E. QUANTITIES (NOT INCL. ACCESS SHAFT)

SHEET 4 OF

1. TUNNEL (IF MULTIPLE, SHOW FOR EACH)

LENGTH	2942' IB - 2980' OB		FT
INSIDE D.O.		OUTSIDE D.O	18'+
CONFIGURATION			
NO. CROSS OVERS, IF MULTIPLE			EA.
TOTAL EXCAVATION			CY
TUNNEL PRESSURE RANGE		PSI	PSI

2. GROUTING (CY)

	EST	ACTUAL
BEHIND TEMP. LINING		
CONSOLIDATION (FACE)		
PREGROUTING		

3. TEMPORARY LINING (IF USED)

DESCRIPTION	QUANTITY

4. FINAL LINING

TYPE: STEEL LINER PLATE

NO. LINERS IF PREFAB OR PRECAST — EA

QUANTITIES IF CAST-IN-PLACE

DESCRIPTION	QUANTITY
CONCRETE	(CY)
REINFORCING	(TONS)
FORMING	(S.F.)

6. INVERT (AND WALKWAYS), ARCH

DESCRIPTION	QUANTITY
CONCRETE	(CY)
REBAR	(TONS)
FORMS	(S.F.)
STRUC STEEL	(TONS)

7. MAJOR UNDERPINNINGS

DESCRIPTION	AREA (S.F.)
CHEMICAL GROUT -	
JEFFERSON JUNIOR H.S.	
7th STREET BRIDGE	
TOTAL	

8. AIRLOCK SYSTEM (IF USED)

MAN LOCKS	
NUMBER	(EA)
LENGTH	(FT)
DIAMETER	(FT)
MUD LOCK	
NUMBER	(EA)
LENGTH	(FT)
DIAMETER	(FT)
BULK HEAD DESIGN	PSIG

9. APPURTENANT STRUCTURES

VENT AND FAN SHAFTS

CONSTRUCTION METHOD: SOLDIER PILES & LAGGING
FORMED CONCRETE WALLS & SLABS

WIDTH (FT)	BREADTH FT	DEPTH FT

WALL THICKNESS

EXCAVATION QUANTITES (CY)

CONCRETE QUANTITIES (CY)

PUMPING STATIONS

CONSTRUCTION METHOD:

CONFIGURATION

DEPTH (FT)	DIAMETER (FT)

EXCAVATION QUANTITIES (CY)

CONCRETE QUANTITIES

OTHER APPURTENANCES (SPECIFY)

DESCRIPTION	EXCAV. (CY)	CONCRETE (CY)

10. SITE PREPARATION & RESTORATION

DESCRIPTION	TYPE	AREA (S.F.)
CLEAR & GRUB		
REMOVAL	PAVING	
RESTORATION	REPAVE	

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F. TYPICAL CREW SIZE AND UTILIZATION (1)

SHEET 5 OF ____

1. CREW –

SHIFTS / DAY

HOURS / SHIFT 2 3

WORKING DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
TUNNEL SUPERINTENDENT	1	1	
WALKER	1	1	
SHIFTER	1	1	
OPERATOR	7	7	
MECHANIC	1	1	
MINER	8	8	
ENGINEER	1	1	
SURVEYOR	2	2	
ELECTRICIAN	1	1	
TOTAL	23	23	
TOTAL			

2. CREW –

SHIFTS / DAY

HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

3. CREW –

SHIFTS / DAY

HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

4. CREW –

SHIFTS / DAY

HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

(1) NOTE CATEGORY OF CREWS (HEADING, SUPPORT SURFACE, SHAFT ETC.) REPORT AS LOGGED

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F. TYPICAL CREW SIZE AND UTILIZATION (1) F2A

SHEET 5 OF ____

1. CREW – Mining Crew

SHIFTS / DAY 3

HOURS / SHIFT 8

WORKING DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Foreman	1	1	1
Shield Operator	1	1	1
Miners	7	7	7
Muck Operator	1	1	1
Conveyor Operator	1	1	1
Locomotive Opr.	2	2	2
TOTAL	13	13	13

2. CREW – Support Crew

SHIFTS / DAY 3

HOURS / SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Foreman	1	1	1
Crane Operator	1	1	1
Crane Oiler	1	1	1
Bottom Men	2	2	2
Compressor Opr	1	1	1
Top Man	1	1	1
TOTAL	7	7	7

3. CREW – Grout Crew

SHIFTS / DAY 3

HOURS / SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Foreman	1	1	1
Nozzlemen	2	2	2
Pumpman	1	1	1
Helpers	2	2	2
TOTAL	6	6	6

4. CREW – Bull Gang

SHIFTS / DAY 3

HOURS / SHIFT 8

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Foreman	1	1	1
Miners	4	4	4
TOTAL	5	5	5

(1) NOTE CATEGORY OF CREWS (HEADING, SUPPORT SURFACE, SHAFT ETC.) REPORT AS LOGGED

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

A. DESCRIPTION

1. PROJECT NAME	1F0012	NUMBER	F1B
2. LOCATION	WASHINGTON D.C.		
3. OWNER	WMATA	ENGINEER	
4. CONTRACTOR			
5. DATES: START		COMPLETE	

6. PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

7. OWNER FURNISHED MATERIAL AND EQUIPMENT LIST

8. OTHER OWNER SUPPLIED COST ITEMS (e.g. INSURANCE)

B. DESIGN INFORMATION

SHEET 1 OF

1. PLAN AND PROFILE ATTACHED:	YES		NO	✓
2. TYPICAL SECTION DRAWING ATTACHED	YES		NO	—
3. TEMPORARY LININGS DETAILS ATTACHED:	YES		NO	✓
4. PERMANENT LININGS DETAILS ATTACHED:	YES		NO	—
5. GEOLOGICAL PROFILE ATTACHED:	YES		NO	✓

6. VERBAL DESCRIPTION OF SOIL CONDITIONS.

SAND - SOME CLAY, BOULDERS & GRAVEL

7. DEWATERING PLAN ATTACHED: YES | NO —

8. GROUND WATER CONDITIONS DESCRIPTION

9. SITE PREPARATION & RESTORATION DESCRIPTION

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

B. DESIGN INFORMATION (CONTINUED)

10. UNDERPINNING DESCRIPTION None

11. UTILITIES. DESCRIPTION

STANDARD UNDER STREET UTILITIES
NO SPECIAL GROUTING, ETC

C. CONSTRUCTION METHODS

SHEET 2 OF

1. FREE AIR	YES	LENGTH (FT)	333K
2. COMPRESSED AIR		LENGTH (FT)	
PSIG MIN	PSIG MAX	PSIG WTD AVG.	

3. DESCRIPTIONS

TUNNEL EXCAVATION

PRIMARY LINING

STEEL RIBS & WOOD LAGGING

FINAL LINING

15" CONCRETE

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

SHEET 3 OF ____

D. MAJOR EQUIPMENT UTILIZED

1. CUTTING AND EXCAVATING	HAND MINING					
MAKE						
MODEL						
TYPE:	ROTATING WHEEL		OSCILLATING ARMS		DIGGING ARM	
	OTHER (SPECIFY)					
CONNECTED HORSE POWER						
NO. USED						
2. SHIELD	MILWAUKEE BOILERS MFG.					
OUTSIDE DIA.	20.7'	LENGTH	21.9'			
NO. OF JACKS		THRUST FORCE (TONS) ~~EACH JACK~~ TOTAL	2,500	NO. OF JACKING MOTORS		
HORSE POWER EA. JACKING MOTOR	-					
NO. SHIELDS USED						
3. MUCKING EQUIPMENT (UNDERGROUND)						
TYPE:						
CONVEYOR: LENGTH	(FT.)	CAPACITY	(T)			
RAIL CARS:	NO.	CAPACITY	(T)			
RUBBER TIRE VEHICLE NO.		CAPACITY	(T)			
COMBINATION (SPECIFY)						
4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)						

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.

GROUTING

DESCRIPTION	CAPACITY	NO.

CONCRETE: INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.

6. VENTING, PUMPING, COMPRESSION, EQUIPMENT

DESCRIPTION	CAPACITY	NO.

7. OTHER (Specify)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

SHEET 5 OF ____

F. TYPICAL CREW SIZE AND UTILIZATION (1)

1. CREW –

SHIFTS / DAY 2	HOURS / SHIFT		
WORKING DESIGNATION	1ST SHIFT	~~3RD~~ 2 SHIFT	~~2ND~~ 3 SHIFT
SUPERINTENDENT	(1)		
FOREMAN	1	1	
OPERATORS	2	2	
LABORERS (MINERS)	6	6	
ELECTRICIAN	1	1	
MECHANIC	2	2	
LOADERS	2	2	
TOTAL (AVERAGE	14	14	
TOTAL			

2. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

3. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

4. CREW –

SHIFTS / DAY	HOURS / SHIFT		
WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

(1) NOTE: CATEGORY OF CREWS (HEADING, SUPPORT SURFACE, SHAFT ETC.) REPORT AS LOGGED

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY OATA

A. DESCRIPTION

1. PROJECT NAME Embarcadero to Montgomery St.	NUMBER 150051-A
2. LOCATION San Francisco, California	
3. OWNER BARTD	ENGINEER PBTB
4. CONTRACTOR	
5. OATES: START 10/2/70	COMPLETE 2/5/71

6. PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

Approximately 1440 ft of twin subway line tunnels.

7. OWNER FURNISHEO MATERIAL AND EQUIPMENT LIST

8. OTHER OWNER SUPPLIED COST ITEMS (e.g. INSURANCE)

B. DESIGN INFORMATION.

SHEET 1 OF -

1. PLAN AND PROFILE ATTACHED:	YES		NO	
2. TYPICAL SECTION DRAWING ATTACHED	YES		NO	
3. TEMPORARY LININGS DETAILS ATTACHED:	YES		NO	
4. PERMANENT LININGS DETAILS ATTACHED:	YES		NO	
5. GEOLOGICAL PROFILE ATTACHED:	YES		NO	

6. VERBAL DESCRIPTION OF SOIL CONDITIONS:

Mostly clay and sand with some hard ground encountered. Ground stood up fairly well.

7. DEWATERING PLAN ATTACHED: YES NO

8. GROUND WATER CONDITIONS DESCRIPTION

Dewatering wells were used throughout.

9. SITE PREPARATION & RESTORATION DESCRIPTION

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY OATA

B. DESIGN INFORMATION (CONTINUED)

10. UNDERPINNING DESCRIPTION

11. UTILITIES DESCRIPTION

C. CONSTRUCTION METHODS

SHEET 2 OF

1. FREE AIR: Yes		LENGTH (FT)	729.7 Ft
2. COMPRESSED AIR: Yes		LENGTH (FT)	709.96 ft
PSIG MIN 0	PSIG MAX 13.82	PSIG WTD AVG.	

3. DESCRIPTIONS

TUNNEL EXCAVATION

Excavation was carried out by a shield used with a muck conveyor with trains. A rubber-tired vehicle was also used.

PRIMARY LINING

Steel liner rings 2½ ft wide

FINAL LINING

Concrete

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

D. MAJOR EQUIPMENT UTILIZED

SHEET 3 OF

1. CUTTING AND EXCAVATING

MAKE

MODEL

TYPE: ROTATING WHEEL | OSCILLATING ARMS | DIGGING ARM

OTHER (SPECIFY) Manual Digging

CONNECTED HORSE POWER

NO. USED

2. SHIELD

OUTSIDE DIA 18.125 Ft. LENGTH

NO. OF JACKS | THRUST FORCE (TONS) EACH JACK 5800 | NO. OF JACKING MOTORS

HORSE POWER EA. JACKING MOTOR

NO. SHIELDS USED

3. MUCKING EQUIPMENT (UNDERGROUND)

TYPE: 24B Eimco Air Muckers

CONVEYOR: LENGTH (FT.) CAPACITY (T)

RAIL CARS: NO. CAPACITY (T)

RUBBER TIRE VEHICLE NO. CAPACITY (T)

COMBINATION (SPECIFY)

4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)

2 portable generators, 1 JD 544 Backhoe, 1 whirley, 2 10-wheel dump trucks, 2 jack legs, 2 breakers, 1 rock jack, 1 950-loader, 1 pickup, 1 550-hopper, 1 Hydynamic crane, 1 8-10cy dump truck, 1 compressor.

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.

GROUTING

DESCRIPTION	CAPACITY	NO.
Grout Agitators		2
Chemical Grout Plant		1
Grout Pump Cars		2

CONCRETE, INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.
Concrete trucks		10
Batch plant		1

6. VENTING, PUMPING, COMPRESSION, EQUIPMENT

DESCRIPTION	CAPACITY	NO.
Battery Locomotives, Trains	15 Ton	1-2
Cranes	10-50 Tons	1-3
Muck Cars		6

7 OTHER (Specify)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

E. QUANTITIES (NOT INCL. ACCESS SHAFT)

SHEET 4 OF

1. TUNNEL (IF MULTIPLE, SHOW FOR EACH)

LENGTH SR-709.96 SR-729.7 FT

INSIDE DIA. 17' 6"

CONFIGURATION Circular

NO. CROSS OVERS, IF MULTIPLE EA

TOTAL EXCAVATION CY

TUNNEL PRESSURE RANGE 2.75 PSI - 13.82 PSI

2. GROUTING (CY)

	EST	ACTUAL
BEHIND TEMP. LINING		1163.5 cy
CONSOLIDATION (FACE)		
PREGROUTING		

3. PRIMARY LINING

DESCRIPTION	QUANTITY
2-1/2 ft. Steel Rings	

4. FINAL LINING

TYPE Concrete

NO. LINERS IF PREFAB OR PRECAST EA

QUANTITIES IF CAST-IN-PLACE

DESCRIPTION	QUANTITY
CONCRETE	(CY)
REINFORCING	(TONS)
FORMING	(S.F.)

6. INVERT (AND WALKWAYS), ARCH

DESCRIPTION	QUANTITY
CONCRETE	(CY)
REBAR	(TONS)
FORMS	(S.F.)
STRUC. STEEL	(TONS)

7. MAJOR UNDERPINNINGS

DESCRIPTION	AREA (S.F.)
TOTAL	

8. AIRLOCK SYSTEM (IF USED)

MAN LOCKS none

NUMBER (EA)

LENGTH (FT)

DIAMETER (FT)

MUD LOCK none

NUMBER (EA)

LENGTH (FT)

DIAMETER (FT)

BULK HEAD DESIGN PSIG

9. APPURTENANT STRUCTURES

VENT AND FAN SHAFTS

CONSTRUCTION METHOD:

WIDTH (FT) BREADTH FT DEPTH FT

WALL THICKNESS

EXCAVATION QUANTITIES (CY)

CONCRETE QUANTITIES (CY)

PUMPING STATIONS

CONSTRUCTION METHOD:

CONFIGURATION

DEPTH (FT) DIAMETER (FT)

EXCAVATION QUANTITIES (CY)

CONCRETE QUANTITIES

OTHER APPURTENANCES (SPECIFY)

DESCRIPTION	EXCAV. (CY)	CONCRETE (CY)

10. SITE PREPARATION & RESTORATION

DESCRIPTION	TYPE	AREA (S.F.)
CLEAR & GRUB		
REMOVAL		
RESTORATION		

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F. TYPICAL CREW SIZE AND UTILIZATION (1)

SHEET 5 OF

1. CREW – Heading Crew

SHIFTS / DAY 2 — HOURS / SHIFT 8

WORKING DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Superintendent	1		
Shift Boss	1		
Heading Engineer	1-2		
Miners	8-13		
Mechanics	1-4		
Walker	1		
Brakeman	1		
Operators	1-2		
Motorman	1		
Laborers	5		
Iron Workers	1		
Oiler	1		
TOTAL	28-29	21	

2. CREW – Surface

SHIFTS / DAY — HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

3. CREW –

SHIFTS / DAY — HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

4. CREW –

SHIFTS / DAY — HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

(1) NOTE. CATEGORY OF CREWS (HEADING, SUPPORT, SURFACE, SHAFT ETC.) REPORT AS LOGGED

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

A. DESCRIPTION

1. PROJECT NAME Lower Market Street — NUMBER 150011
2. LOCATION San Francisco, Calif.
3. OWNER BARTD — ENGINEER PBTB
4. CONTRACTOR Shea-Ball-Granite-Olsen
5. DATES: START 7/7/67 — COMPLETE 4/10/70

6. PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES)

Four-bore (two bores on each of 2 levels) stacked steel ring lined. Total drive of 6,283 LF. Each heading approximately 1570 LF. Includes 2 cross over passages and 8 terminating tunnel ends.

7. OWNER FURNISHED MATERIAL AND EQUIPMENT LIST

Segmented steel liners
Electrical switchgear
Lighting fixtures
Vent fans with drivers, controls + dampers
Power distribution panels

8. OTHER OWNER SUPPLIED COST ITEMS (e.g. INSURANCE)

Right-of-ways
System wide Workmen's compensation Insur.

B. DESIGN INFORMATION.

SHEET 1 OF

1. PLAN AND PROFILE ATTACHED	YES		NO	
2. TYPICAL SECTION DRAWING ATTACHED	YES		NO	
3. TEMPORARY LININGS DETAILS ATTACHED	YES		NO	
4. PERMANENT LININGS DETAILS ATTACHED	YES		NO	
5. GEOLOGICAL PROFILE ATTACHED	YES		NO	

6. VERBAL DESCRIPTION OF SOIL CONDITIONS.

Soil was mostly clay and sand with some solid blue clay. The ground was mostly cohesive except for occassional areas of running sand. Some areas were very firm in consistency.

7. DEWATERING PLAN ATTACHED YES NO

8. GROUND WATER CONDITIONS DESCRIPTION

There were a few instances where water appeared at the face. Wetness stayed mostly below a level of "wet" but there were instances of running water.

9. SITE PREPARATION & RESTORATION DESCRIPTION

Appendix A-1. (Continued)

B. DESIGN INFORMATION (CONTINUED)

10. UNDERPINNING DESCRIPTION

11. UTILITIES, DESCRIPTION

Remove, relocate, support or replace existing utility lines such as storm drains, sanitary sewers, water, gas, lighting and power distribution, and Muni lines.

C. CONSTRUCTION METHODS

SHEET 2 OF

1. FREE AIR:	LENGTH (FT)	6,283
2. COMPRESSED AIR: not used	LENGTH (FT)	
PSIG MIN	PSIG MAX	PSIG WTD AVG.

3. DESCRIPTIONS

TUNNEL EXCAVATION

Excavation for tunnel SL was with a 17.92 ft shield with a digger arm. Tunnels SR, TR, and TL used an 18.08 ft. shield with a digger arm. All tunnels used a conveyor belt and train for muck removal. About one-half of the mining was done by hand.

PRIMARY LINING

Segmented 2-1/2 ft. steel liners

FINAL LINING

Concrete

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

D. MAJOR EQUIPMENT UTILIZED

SHEET 3 OF

1. CUTTING AND EXCAVATING

- MAKE
- MODEL
- TYPE: ROTATING WHEEL ☐ OSCILLATING ARMS ☐ DIGGING ARM X
- OTHER (SPECIFY) Hand Mining
- CONNECTED HORSE POWER: Not Available
- NO. USED

2. SHIELD

- OUTSIDE DIA. 18.08 ft. LENGTH
- NO. OF JACKS; THRUST FORCE (TONS) EACH JACK: SL - 5800 TR - 4800 SR+TL - 3600
- HORSE POWER EA. JACKING MOTOR
- NO. SHIELDS USED 1

3. MUCKING EQUIPMENT (UNDERGROUND)

- TYPE: Conveyor Belt and trains
- CONVEYOR: LENGTH (FT.) CAPACITY (T)
- RAIL CARS. NO. CAPACITY (T)
- RUBBER TIRE VEHICLE NO. CAPACITY (T)
- COMBINATION (SPECIFY)

4. MUCKING EQUIPMENT UNDERGROUND TO SURFACE (DESCRIBE)

5. OTHER MATERIAL HANDLING EQUIPMENT (SPECIFY) SURFACE TO HEADING

LINERS (PRE CAST)

DESCRIPTION	CAPACITY	NO.

GROUTING

DESCRIPTION	CAPACITY	NO.
Grout Machine		1

CONCRETE INVERT (AND WALKWAYS)

DESCRIPTION	CAPACITY	NO.
Truck Mounted Thompson Concrete Pump		1

6. VENTING, PUMPING, COMPRESSION, EQUIPMENT

DESCRIPTION	CAPACITY	NO.
Battery Locomotives		1-2
Eimco Air Mucker		1
Cranes	60 tons	1-2

7. OTHER (Specify)

Appendix A-1. (Continued)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

E. QUANTITIES (NOT INCL. ACCESS SHAFT)

SHEET 4 OF ____

1. TUNNEL (IF MULTIPLE, SHOW FOR EACH)		
LENGTH	1567	FT
INSIDE DIA. 16' 6"	OUTSIDE DIA.	
CONFIGURATION	2 single track bores on each of 2 levels	
NO. CROSS OVERS, IF MULTIPLE	2	EA.
TOTAL EXCAVATION		CY
TUNNEL PRESSURE RANGE	0 PSI	PSI

2. GROUTING (CY)	EST	ACTUAL
BEHIND TEMP. LINING		
CONSOLIDATION (FACE)		
PREGROUTING		

3. PRIMARY LINING	
DESCRIPTION	QUANTITY
Segmented steel rings	

4. FINAL LINING	
TYPE Concrete	
NO. LINERS IF PREFAB OR PRECAST	EA
QUANTITIES IF CAST-IN-PLACE	
DESCRIPTION	QUANTITY
CONCRETE	(CY)
REINFORCING	(TONS)
FORMING	(S.F.)

6. INVERT (AND WALKWAYS), ARCH	
DESCRIPTION	QUANTITY
CONCRETE	(CY)
REBAR	(TONS)
FORMS	(S.F.)
STRUC. STEEL	(TONS)

7. MAJOR UNDERPINNINGS	
DESCRIPTION	AREA (S.F.)
TOTAL	

8. AIRLOCK SYSTEM (IF USED)	
MAN LOCKS none	
NUMBER	(EA)
LENGTH	(FT)
DIAMETER	(FT)
MUD LOCK none	
NUMBER	(EA)
LENGTH	(FT)
DIAMETER	(FT)
BULK HEAD DESIGN	PSIG

9. APPURTENANT STRUCTURES		
VENT AND FAN SHAFTS		
CONSTRUCTION METHOD		
WIDTH (FT)	BREADTH FT	DEPTH FT
WALL THICKNESS		
EXCAVATION QUANTITIES		(CY)
CONCRETE QUANTITIES		(CY)
PUMPING STATIONS		
CONSTRUCTION METHOD:		
CONFIGURATION		
DEPTH (FT)	DIAMETER (FT)	
EXCAVATION QUANTITIES		(CY)
CONCRETE QUANTITIES		
OTHER APPURTENANCES (SPECIFY)		
DESCRIPTION	EXCAV (CY)	CONCRETE (CY)

10. SITE PREPARATION & RESTORATION		
DESCRIPTION	TYPE	AREA (S.F.)
CLEAR & GRUB		
REMOVAL		
RESTORATION		

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION

CASE HISTORY DATA

F. TYPICAL CREW SIZE AND UTILIZATION (1)

SHEET 5 OF ____

1. CREW –

SHIFTS / DAY 3 — HOURS / SHIFT 8

WORKING DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT
Compressor Houseman	1	1	1
Laborers			
Mechanics	1-5	1-5	1-5
Operator	1-2	1-2	1-2
Motorman	1	1	1
Brakeman	1	1	1
Oiler	1	1	1
Shifter	1	1	1
Miners	7-13	7-13	7-13
Surveyors	3-5	3-5	3-5
Iron Workers			
Grout Crew			
Superintendent	1	1	1
Walkers	1	1	1
TOTAL			

2. CREW –

SHIFTS / DAY — HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

3. CREW –

SHIFTS / DAY — HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

4. CREW –

SHIFTS / DAY — HOURS / SHIFT

WORK DESIGNATION	1ST SHIFT	2ND SHIFT	3RD SHIFT

(1) NOTE: CATEGORY OF CREWS (HEADING, SUPPORT, SURFACE, SHAFT ETC.) REPORT AS LOGGED

Appendix A-1. (Continued)

Appendix A-2

A record of the weekly average, for each tunnel studied, of the

- progress rate,
- down hours and
- soils encountered.

All data, including those concluded to be outliers, are listed. These data are also available on the punched-card data sets submitted.

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
300.83	15.00	15.00	8.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
300.68	32.50	47.50	32.00	.00	5.00	.00	.00	2.50	.00	7.50	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
300.35	187.50	235.00	110.00	.00	.00	.00	.00	10.60	.00	10.60	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
298.48	97.50	332.50	41.00	.00	.00	.00	.00	78.00	1.00	79.00	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
297.50	220.00	552.50	111.00	.00	2.00	.00	4.00	3.00	.00	9.00	.50	.50	.00	.00	.00	.00	1.00	.00	.20
295.30	127.50	680.00	56.00	.00	5.00	.00	.00	17.00	.00	22.00	.50	.50	.00	.00	.00	.00	1.00	.00	.20
294.03	145.00	825.00	54.00	.00	.00	.00	.00	66.50	.00	66.50	.50	.50	.20	.00	.00	.00	1.00	.00	.20
292.56	260.00	1085.00	94.00	.00	7.00	.00	.00	19.00	.00	26.00	.50	.50	.20	.00	.00	.00	1.00	.00	.20
289.98	292.50	1377.50	94.00	.00	.00	.00	.00	26.50	.00	26.50	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
287.05	125.00	1502.50	64.00	.00	19.00	.00	.00	17.00	.00	36.00	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
285.80	155.00	1657.50	77.00	.00	29.00	.00	.00	14.00	.00	43.00	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
284.25	192.50	1650.00	90.00	.00	8.00	.00	.00	22.00	.00	30.00	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
282.33	110.00	1960.00	50.00	.00	56.00	.00	.00	13.50	.00	69.50	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
281.23	90.00	2050.00	112.00	.00	3.00	.00	.00	5.00	.00	8.00	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
280.33	250.00	2300.00	86.00	.00	15.00	.00	.00	18.50	.00	33.50	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
277.63	257.50	2557.50	82.00	.00	19.50	.00	.00	18.50	.00	38.00	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
275.25	300.00	2857.50	95.00	.00	5.50	.00	4.00	15.50	.00	25.00	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
272.25	245.00	3102.50	100.00	.00	16.00	.00	.00	4.00	.00	20.00	.15	1.00	.15	.00	.00	.00	1.00	.00	.20
269.80	237.50	3340.00	88.00	.00	22.00	.00	5.00	4.50	.00	31.50	.15	1.00	.15	.00	.00	.00	1.00	.00	.20
267.43	257.50	3597.50	94.00	.00	7.00	.00	.00	19.50	.00	26.50	.10	1.00	1.00	1.00	.80	.00	1.00	.00	.50

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
264.85	257.50	3855.00	95.00	.00	12.50	.00	.00	13.00	.00	25.50	.15	1.00	.15	.00	.00	.00	1.00	.00	.50
262.26	247.50	4102.50	92.00	.00	20.50	.00	.00	8.00	.00	28.50	.15	1.00	.15	.00	.00	.00	1.00	.00	.50
259.80	195.00	4297.50	83.00	.00	22.00	.00	.00	15.00	.00	37.00	.15	1.00	.15	.00	.00	.00	1.00	.00	.50
257.85	47.50	4345.00	41.00	.00	76.00	.00	.00	3.00	.00	79.00	.15	1.00	.15	.00	.00	.00	1.00	.00	.50
257.38	80.00	4425.00	56.00	.00	.00	.00	.00	16.50	.00	16.50	.15	1.00	.15	1.00	.80	.00	1.00	.00	.50

Appendix A-2. Average Weekly Progress Data

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
300.63	20.00	20.00	32.00	1.50	.00	.00	.00	5.00	.00	6.50	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
300.63	32.50	52.50	34.00	2.00	2.00	.00	.00	2.50	.00	6.50	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
300.30	122.50	175.00	76.00	.00	34.50	.00	.00	5.00	5.00	44.50	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
299.08	160.00	335.00	89.00	3.00	27.00	.00	.00	1.00	.00	31.00	.00	1.00	.00	.00	.00	.00	1.00	.00	.20
297.28	220.00	555.00	113.00	4.00	.00	.00	.00	1.50	1.50	7.00	.50	.50	.00	.00	.00	.00	1.00	.00	.20
295.06	237.50	792.50	102.00	.00	.00	.00	.00	18.50	.00	18.50	.50	.50	.20	.00	.00	.00	1.00	.00	.20
292.70	370.00	1162.50	112.00	.00	1.50	.00	.00	5.00	1.50	8.00	.50	.50	.20	.00	.00	.00	1.00	.00	.20
289.00	187.50	1350.00	60.00	.00	2.00	.00	.00	13.50	2.00	17.50	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
287.13	137.50	1487.50	63.00	.00	.00	.00	.00	14.50	.50	15.00	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
285.75	27.50	1515.50	10.00	.00	2.00	.00	.00	108.00	.00	110.00	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
285.48	180.00	1695.00	84.00	1.00	.00	14.00	13.00	7.50	.00	35.50	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
283.68	175.00	1870.00	93.00	.00	16.00	.00	.00	11.00	.00	27.00	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
281.93	65.00	1935.00	59.00	.00	57.00	.00	.00	4.00	.00	61.00	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
280.96	22.50	1987.50	28.00	.00	86.00	.00	.00	4.50	.00	92.50	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
280.75	175.00	2162.50	66.00	.00	40.50	12.50	.00	1.00	.00	54.00	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
279.00	332.50	2495.00	104.00	.00	6.00	.00	.00	10.50	.00	16.50	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
275.67	82.50	2577.50	56.00	.00	58.00	.00	.00	5.50	.00	63.50	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
274.85	210.00	2787.50	101.00	.00	9.00	.00	.00	10.00	.00	19.00	.10	1.00	.35	.00	.00	.00	1.00	.00	.20
272.75	292.50	3080.00	94.00	.00	6.00	.00	.00	20.00	.50	26.50	.15	1.00	.15	.00	.00	.00	1.00	.00	.20
269.83	205.00	3285.00	95.00	.00	14.50	.00	.00	9.50	.50	24.50	.15	1.00	.15	.00	.00	.00	1.00	.00	.20

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
267.78	230.00	3510.00	92.00	.00	21.00	.00	.00	6.00	.50	27.50	.10	1.00	.10	.00	.00	.00	1.00	.00	.20
265.28	285.00	3795.00	95.00	.00	7.00	.00	.00	16.50	1.50	25.00	.10	1.00	1.00	1.00	.80	.00	1.00	.00	.50
262.42	325.00	4120.00	104.00	.00	7.50	.00	.00	8.50	.00	16.00	.15	1.00	.15	.00	.00	.00	1.00	.00	.50
259.17	160.00	4280.00	106.00	.00	7.00	.00	.00	5.50	.00	12.50	.15	1.00	.15	.00	.00	.00	1.00	.00	.50
257.58	110.00	4390.00	101.00	.00	.00	.00	.00	11.00	.00	11.00	.15	1.00	.15	1.00	.80	.00	1.00	.00	.50

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
BR/BL TUNNELS
BERKELEY, CALIFORNIA

				DOWNHOURS - HOURS/WEEK BY CAUSE							RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK								
STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
1224.92	20.00	28.00	76.00	4.00	.00	.00	.00	8.00	.00	12.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1224.72	62.00	90.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1224.10	73.00	163.00	118.00	.00	.00	.00	.00	2.00	.00	2.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1223.37	49.00	212.00	111.00	.00	.00	.00	3.00	1.00	5.00	9.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1222.88	52.00	264.00	114.00	3.00	.00	.00	.00	.00	3.00	6.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1222.36	56.00	320.00	119.00	.00	.00	.00	1.00	.00	.00	1.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1221.80	47.00	367.00	80.00	34.00	.00	.00	.00	3.00	3.00	40.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1221.33	76.00	443.00	118.00	.00	.00	.00	.00	2.00	.00	2.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1220.57	86.00	529.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1219.71	87.00	616.00	116.00	2.00	.00	.00	.00	.00	.00	2.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1218.84	96.00	712.00	111.00	2.00	.00	.00	4.00	3.00	.00	9.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1217.88	59.00	771.00	76.00	2.00	.00	.00	.00	.00	.00	2.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1217.29	91.00	862.00	117.00	2.00	.00	.00	.00	1.00	.00	3.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1216.38	82.00	944.00	113.00	5.00	.00	.00	1.00	1.00	.00	7.00	.00	.50	.50	.00	.00	.00	1.00	.00	.00
1215.56	72.00	1016.00	99.00	20.00	.00	.00	1.00	.00	.00	21.00	.00	.00	.00	.50	.00	.00	1.00	.00	.00
1214.84	83.00	1099.00	119.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.50	.00	.00	1.00	.00	.00
1214.01	58.00	1157.00	94.00	2.00	.00	.00	.00	.00	.00	2.00	.00	.00	.00	.50	.00	.00	1.00	.00	.00
1213.43	69.00	1225.00	96.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	1.00	.00	.00
1212.74	65.00	1290.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1212.09	84.00	1374.00	119.00	.00	.00	.00	1.00	.00	.00	1.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
BR/BL TUNNELS
BERKELEY, CALIFORNIA

				DOWNHOURS - HOURS/WEEK BY CAUSE							RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK								
STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
1211.25	65.00	1459.00	119.00	.00	.00	.00	1.00	.00	.00	1.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1210.40	15.00	1474.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1210.25	5.00	1479.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1224.43	119.00	1598.00	115.00	.00	.00	.00	4.00	1.00	.00	5.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1223.24	74.00	1672.00	78.00	.00	.00	.00	2.00	.00	.00	2.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1222.50	136.00	1810.00	119.00	.00	.00	.00	1.00	.00	.00	1.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1221.12	133.00	1943.00	112.00	.00	.00	.00	8.00	.00	.00	8.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1219.79	116.00	2059.00	103.00	.00	.00	.00	17.00	.00	.00	17.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1218.63	140.00	2199.00	118.00	.00	.00	.00	2.00	.00	.00	2.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1217.23	130.00	2329.00	112.00	.00	.00	.00	7.00	1.00	.00	8.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1215.93	39.00	2368.00	69.00	.00	.00	.00	51.00	.00	.00	51.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
1215.54	94.00	2462.00	117.00	1.00	.00	.00	1.00	1.00	.00	3.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1214.60	84.00	2546.00	116.00	.00	.00	.00	4.00	.00	.00	4.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1213.76	104.00	2650.00	119.00	.00	.00	.00	.00	1.00	.00	1.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1212.72	96.00	2746.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1211.76	64.00	2810.00	77.00	43.00	.00	.00	.00	.00	.00	43.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1211.12	78.00	2888.00	118.00	1.00	.00	.00	.00	1.00	.00	2.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00
1210.34	15.00	2903.00	120.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00	1.00	.00	.00

Appendix A-2. (Continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TR TUNNEL
SAN FRANCISCO, CALIFORNIA

PROGRESS AND PRODUCTION

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
48286.52	47.43	47.43	63.08	.50	.00	.00	.50	.00	.00	1.00	.00	1.00	.00	.00	.00	.00	.50	.50	.50
48333.95	147.30	194.73	114.84	.00	.00	.00	1.75	1.83	.00	3.58	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
48481.45	167.34	362.07	112.76	1.15	1.25	.50	.50	.00	.00	3.40	.00	1.00	.00	.00	.00	.00	1.00	.00	.13
48648.79	204.78	566.85	115.59	1.32	1.50	.67	.00	.25	.00	3.74	.00	1.00	.00	.00	.00	.00	.90	.00	.29
48853.57	129.89	696.74	99.44	8.93	5.56	.25	.42	3.38	.00	18.56	.00	1.00	.00	.00	.00	.00	.00	1.00	.33
48983.48	192.22	888.96	99.37	5.59	8.67	1.42	.25	.50	.00	16.43	.00	1.00	.00	.00	.00	.00	.40	.60	.00
49175.70	227.27	1116.23	102.36	.50	2.29	1.25	8.67	.00	.00	12.92	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49402.97	237.15	1353.38	108.40	.00	6.59	.75	2.02	.83	.00	10.19	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49640.12	109.83	1463.21	118.66	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.45	.55	.10
49749.95	52.28	1515.49	97.62	7.41	3.17	.00	.00	4.67	.00	15.25	.00	1.00	.00	.00	.00	.00	.00	1.00	.00
49802.23	34.99	1550.48	103.95	1.17	.00	.00	.00	.00	.00	1.17	.00	1.00	.00	.00	.00	.00	.00	1.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TL TUNNEL
SAN FRANCISCO, CALIFORNIA

PROGRESS AND PRODUCTION

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
48264.02	44.76	44.76	97.85	.00	.00	.00	1.40	3.00	.00	4.40	.00	1.00	.00	.00	.00	.00	.00	.80	.40
48330.03	92.59	137.34	112.67	4.67	.00	.00	.00	2.16	.00	6.83	.00	1.00	.00	.00	.34	.00	.60	.40	.00
48421.36	172.27	309.61	114.59	.00	.00	.00	1.91	.00	.00	1.91	.00	1.00	.00	.00	.35	.00	1.00	.00	.00
48593.63	159.82	469.43	93.00	.00	.50	.50	.00	.00	.00	1.00	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
48753.45	159.88	629.31	93.58	1.25	.00	.50	.00	.00	.00	1.75	.00	1.00	.00	.00	.00	.00	.90	.10	.10
48913.33	197.37	826.68	111.70	.38	2.25	3.42	.83	.00	.00	6.88	.00	1.00	.00	.00	.00	.00	.90	.02	.08
49113.19	227.36	1054.04	102.59	2.42	.50	4.33	7.66	.00	.00	14.91	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49340.55	227.37	1281.41	105.10	3.16	5.43	2.16	2.27	.38	.00	13.40	.00	1.00	.00	.00	.00	.00	.80	.10	.30
49567.92	169.95	1451.36	92.24	5.55	2.50	2.25	13.67	2.09	.00	26.06	.00	1.00	.00	.00	.00	.00	.60	.13	.50
49737.87	64.93	1516.29	116.50	.00	.00	.00	.00	1.00	.00	1.00	.00	1.00	.00	.00	.00	.00	.00	1.00	.15
49802.80	35.00	1551.29	75.66	.00	.00	.00	.00	2.92	.00	2.92	.00	1.00	.00	.00	.00	.00	.00	1.00	.00

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1SO011
SR TUNNEL
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
48284.00	42.50	42.50	55.42	.33	.00	.00	20.00	1.50	.00	21.83	.00	1.00	.00	.00	.50	.00	1.00	.00	.00
48328.87	122.60	165.10	113.08	.00	.00	.00	3.17	2.91	.00	6.08	.00	1.00	.00	.00	.50	.00	.70	.20	.31
48451.47	47.53	212.63	44.24	.33	.00	.00	.59	.67	.00	1.59	.00	1.00	.00	.00	.50	.00	1.00	.00	.12
48499.00	112.40	325.03	84.93	.00	2.67	.50	6.33	.67	.00	10.17	.00	1.00	.00	.00	.50	.00	.70	.20	.00
48611.40	164.88	489.91	113.08	.75	.00	.50	4.42	.00	.00	5.67	.00	1.00	.00	.00	.60	.00	.70	.10	.00
48776.28	164.84	654.75	106.81	1.75	4.50	.00	1.94	1.08	.00	9.27	.00	1.00	.00	.00	.40	.00	.30	.70	.00
48941.12	184.57	839.32	100.83	2.56	5.50	.00	5.92	.00	.00	14.00	.00	1.00	.00	.00	.50	.00	.50	.70	.00
49125.69	192.29	1031.61	91.23	1.83	.00	.00	26.86	.00	.00	28.69	.00	1.00	.00	.00	.60	.00	1.00	.00	.00
49317.98	204.73	1236.34	117.00	.42	.00	.00	.00	.00	.00	.42	.00	1.00	.00	.00	.48	.00	.96	.00	.00
49522.71	179.41	1415.75	95.42	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.50	.00	1.00	.00	.00
49702.12	137.19	1552.94	84.08	.00	.00	.00	.25	12.25	.00	12.50	.00	1.00	.00	.00	.60	.00	1.00	.00	.00

KEY FOR SOIL TYPES

I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER

0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
SL TUNNEL
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
48277.05	29.93	29.93	109.33	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
48306.98	79.66	109.53	116.16	.50	.00	.00	.00	.00	.00	.50	.00	1.00	.00	.00	.00	.00	.00	1.00	.00
48366.64	99.92	209.45	112.17	.00	1.00	.50	1.50	1.25	2.50	6.75	.00	1.00	.00	.00	.00	.00	.00	1.00	.50
48466.56	117.50	326.95	112.42	.00	.00	.75	.00	.50	2.25	3.50	.00	1.00	.00	.00	.00	.00	.00	1.00	.50
48604.06	59.98	386.93	57.67	.00	.00	2.50	.00	5.50	.00	8.00	.00	1.00	.00	.00	.00	.00	.00	1.00	.00
48664.04	138.90	525.83	108.50	1.25	.50	6.75	.00	.25	.00	8.75	.00	1.00	.00	.00	.00	.00	.00	1.00	.00
48802.94	113.40	639.23	81.17	1.58	4.50	3.33	.00	.00	.00	9.41	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
48916.34	157.48	796.72	105.58	.50	.50	2.00	2.00	.75	.00	5.75	.00	1.00	.00	.00	.00	.00	1.00	.00	.25
49073.83	54.89	851.61	88.90	.00	2.00	2.00	.00	.00	.00	4.00	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49128.72	129.64	981.25	92.08	2.10	19.83	2.16	.00	1.33	.00	25.42	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49258.36	134.84	1116.09	98.42	.33	21.75	.00	.00	.00	.00	22.08	.00	1.00	.00	.00	.00	.00	.00	1.00	.00
49393.20	179.65	1295.74	112.09	4.16	2.25	.00	.00	.00	.00	6.41	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49572.85	162.12	1457.86	63.95	9.83	.50	1.50	16.56	.50	.00	28.89	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
49734.97	107.33	1565.19	74.83	.00	.00	1.50	.00	3.83	.00	5.33	.00	1.00	.00	.00	.00	.00	1.00	.00	.00

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT
CONTRACT NUMBER 1S0051A
SR TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
51352.14	22.50	27.46	66.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.40	.00	.60	.38	.30
51332.06	67.50	94.96	110.25	1.25	.00	.00	3.25	3.00	.00	7.50	.00	1.00	.00	.00	.00	.00	.50	.40	.70
51262.08	42.50	137.46	52.34	7.83	.00	.00	.00	2.50	.00	10.33	.00	1.00	.00	.00	.00	.00	.20	.20	.75
51219.58	52.78	190.24	74.67	2.00	.00	.00	.33	.00	.00	2.33	.00	1.00	.00	.00	1.00	.00	1.00	.00	.34
51166.80	87.22	277.46	106.69	4.24	.00	.00	3.50	1.08	.33	9.15	.00	1.00	.00	.00	.00	.00	.30	.40	.32
51079.58	107.50	384.96	100.64	8.99	.00	1.67	2.95	2.42	1.25	17.28	.00	1.00	.00	.00	.30	.00	.50	.30	.34
50972.06	92.50	477.46	76.25	.83	.00	.00	1.83	2.75	.00	5.41	.00	1.00	.00	.00	.50	.00	1.00	.00	.20
50879.58	87.50	564.96	73.26	.92	.00	.00	2.17	4.25	.00	7.34	.00	1.00	.00	.00	1.00	.00	1.00	.00	.00
50792.08	122.50	687.46	105.52	.00	.00	1.33	2.25	5.58	.00	9.16	.00	1.00	.00	.00	.30	.00	.70	.00	.20
50669.58	22.50	709.96	37.75	.00	.00	.00	.00	11.75	.00	11.75	.00	1.00	.00	.00	.50	.00	.70	.00	.10

KEY FOR SOIL TYPES
- I - SILT AND CLAY
- II - CLAY AND SAND
- III - SAND AND GRAVEL
- IV - COBBLES AND BOULDERS
- V - CEMENTED GROUND
- VI - PEAT AND TRASH
- VII - COHESIVE GROUND
- VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
- 0 = DRY
- .25 = MOIST
- .50 = WET
- .75 = RUNNING WATER
- 1 = FLOODED

PROGRESS AND PRODUCTION

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0051A
SL TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
51342.00	52.42	85.00	112.36	1.00	.00	.00	2.17	1.00	.00	4.17	.00	1.00	.00	.00	.50	.00	.80	.10	.40
51269.58	67.50	152.50	94.08	1.15	.00	.00	16.38	.25	.00	17.78	.00	1.00	.00	.00	.30	.00	.70	.20	.75
51222.08	67.50	220.00	96.44	6.60	.00	.00	7.25	3.09	.00	17.14	.00	1.00	.00	.00	.30	.00	.90	.10	.25
51154.58	60.00	280.00	78.36	1.08	.00	.00	2.50	.00	.00	3.58	.00	1.00	.00	.00	.20	.00	1.00	.00	.20
51094.58	70.00	350.00	79.50	1.00	.00	.00	1.08	.00	.00	2.08	.00	1.00	.00	.00	.00	.00	1.00	.00	.15
51024.28	107.20	457.20	106.03	3.00	.00	.00	3.25	3.92	.00	10.17	.00	1.00	.00	.00	.00	.00	.90	.00	.10
50917.08	107.50	564.70	110.10	2.32	.00	.00	2.25	1.75	.00	6.32	.00	1.00	.00	.00	.00	.00	1.00	.00	.00
50809.58	125.00	689.70	103.49	3.58	.00	.00	4.68	3.22	.00	11.68	.00	1.00	.00	.00	.50	.00	1.00	.00	.00
50684.58	40.00	729.70	49.46	.00	.00	.00	.75	6.26	.00	7.01	.00	1.00	.00	.00	.50	.00	1.00	.00	.00

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-2S
CHICAGO, ILLINOIS

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
432.00	24.00	24.00	25.50	.00	.00	8.00	.00	.00	.00	6.00	1.00	.00	.00	.33	.00	.00	.00	1.00	1.00
456.00	14.00	36.00	16.00	.00	.00	4.00	.00	24.00	.00	28.00	1.00	.00	.00	.00	.00	.00	.00	1.00	1.00
470.00	92.00	130.00	44.00	.00	6.00	.00	.00	.00	.00	6.00	1.00	.00	.00	.00	.00	.00	.00	.75	1.00
562.00	60.00	210.00	25.00	.00	4.00	.00	.00	20.00	.00	24.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
642.00	4.00	214.00	3.00	.00	5.00	.00	.00	.00	.00	5.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
646.00	26.00	242.00	14.00	.00	32.00	4.00	.00	.00	.00	36.00	1.00	.00	.00	1.00	.00	.00	.00	1.00	.00
674.00	23.00	265.00	16.00	.00	4.00	.00	.00	.00	.00	4.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
697.00	19.00	284.00	10.00	.00	.00	.00	.00	6.00	.00	8.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
714.00	74.00	356.00	30.00	.00	4.00	16.00	.00	.00	.00	20.00	1.00	.00	.00	.40	.00	.00	1.00	.00	.00
768.00	52.00	410.00	18.00	.00	6.00	15.00	.00	.00	.00	21.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
840.00	180.00	590.00	40.00	.00	.00	8.00	.00	.00	.00	6.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
1020.00	116.00	706.00	25.50	.00	10.00	10.50	.00	2.50	.00	23.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
1136.00	132.00	838.00	28.00	.00	13.00	.00	.00	5.00	.00	18.00	1.00	.00	.00	1.00	.00	.00	1.00	.20	.20
1229.00	256.00	1094.00	38.00	.00	2.00	6.50	.00	3.50	.00	12.00	1.00	.00	.00	.20	.00	.00	.80	.00	.00
1465.00	268.00	1362.00	38.00	.00	.00	.00	.00	12.00	.00	12.00	.90	.10	.00	.00	.00	.00	1.00	.00	.00
1753.00	104.00	1466.00	16.50	.00	17.00	5.50	.00	5.00	.00	27.50	.00	.20	.80	1.00	.00	.00	1.00	.00	.00
1857.00	44.00	1510.00	12.00	.00	.00	6.50	.00	.00	23.00	29.50	1.00	.00	1.00	1.00	.00	.00	.00	.00	.00
1901.00	20.00	1530.00	12.00	.00	.00	4.00	.00	.00	.00	4.00	1.00	.00	1.00	.00	.00	.00	.00	1.00	.00
1921.00	56.00	1586.00	41.50	.00	2.50	.00	.00	6.00	.00	8.50	.00	.00	1.00	.20	.00	.00	.00	.50	.00
1977.00	82.00	1668.00	33.00	.00	8.00	.00	.00	5.00	.00	13.00	.00	.00	1.00	1.00	.00	.00	.00	.50	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-2S
CHICAGO, ILLINOIS

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
2059.00	154.00	1822.00	38.50	.00	.00	5.50	.00	6.00	.00	11.50	.00	.00	1.00	1.00	.00	.00	.70	.00	.00
2213.00	180.00	2002.00	37.00	.00	.00	.00	.00	3.00	10.00	13.00	.50	.20	.50	.20	.00	.00	1.00	.00	.00
2393.00	73.00	2075.00	34.00	1.00	.00	.00	.00	11.00	2.00	14.00	.80	.00	.20	1.00	.00	.00	.00	.50	.00
2466.00	164.00	2239.00	41.00	4.00	.00	2.00	.00	1.00	.00	7.00	.40	.10	.60	.10	.00	.00	.00	.50	.00
2630.00	35.00	2274.00	19.00	22.00	3.00	.00	.00	.00	.00	25.00	.40	.10	.60	.10	.00	.00	.00	.50	.00
2665.00	64.00	2338.00	23.00	.00	.00	.00	.00	2.00	19.00	21.00	1.00	.00	.00	.00	.00	.00	.00	1.00	.00
2729.90	175.00	2513.00	31.00	6.00	6.00	.00	.00	2.00	.00	16.00	1.00	.00	.00	.00	.00	.00	.00	1.00	.00
2904.00	320.00	2833.00	45.00	.00	.00	.00	.00	5.00	.00	5.00	1.00	.00	.40	.40	.00	.00	.50	.00	.00
3224.00	208.00	3041.00	25.00	.00	6.00	.00	.00	5.00	.00	11.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
3432.00	308.00	3349.00	39.00	.00	.00	3.00	.00	.00	8.00	11.00	.80	.00	.20	.00	.00	.00	1.00	.00	.00
3740.00	276.00	3625.00	37.00	.00	3.00	.00	.00	10.00	.00	13.00	.90	.10	.00	1.00	.00	.00	.00	1.00	.00
4016.00	228.00	3853.00	31.00	.00	.00	.00	.00	9.00	10.00	19.00	.80	.20	.00	.00	.00	.00	1.00	.00	.00
4244.00	376.00	4229.00	45.00	.00	.00	.00	.00	.00	.00	.00	.90	.00	.10	.00	.00	.00	1.00	.00	.00
4620.00	216.00	4445.00	22.00	.00	.00	.00	.00	6.00	10.00	16.00	.80	.00	.20	.00	.00	.00	.50	.50	.00
4836.00	280.00	4725.00	34.00	.00	.00	2.00	.00	4.00	.00	6.00	.80	.00	.20	.25	.00	.00	.00	.00	.00
5116.00	152.00	4877.00	23.50	.00	.00	.00	.00	3.50	11.00	14.50	.80	.00	.20	.00	.00	.00	.00	.00	.25
5268.00	300.00	5177.00	37.00	.00	.00	10.00	.00	1.00	.00	11.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
5568.00	304.00	5481.00	37.00	.00	.00	2.00	.00	1.00	10.00	13.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
5872.00	400.00	5881.00	45.00	.00	.00	.00	1.00	4.00	.00	5.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
6272.00	286.00	6167.00	33.50	.00	.00	.00	.00	6.50	10.00	16.50	1.00	.00	.00	.00	.00	.00	.00	.20	.40

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-25
CHICAGO, ILLINOIS

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
6558.00	178.00	6345.00	31.00	.00	.00	.00	.00	19.00	.00	19.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.60
6736.00	100.00	6445.00	30.00	.00	3.00	.00	.00	12.00	5.00	20.00	.00	.00	1.00	.00	.60	.00	.00	1.00	.60
6836.00	46.00	6493.00	25.00	3.00	7.00	.00	.00	13.00	.00	23.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.60
6864.00	26.00	6519.00	17.00	.00	12.00	.00	.00	7.00	8.00	27.00	.00	.00	1.00	.20	.00	.00	.00	1.00	.00
6910.00	46.00	6565.00	26.00	.00	.00	12.00	.00	8.00	.00	20.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.00
6956.00	98.00	6663.00	33.00	.00	.00	3.00	.00	4.00	8.00	15.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.00
7054.00	162.00	6825.00	36.00	.00	.00	.00	.00	12.00	.00	12.00	.00	.00	1.00	.00	.00	.00	.00	1.00	.00
7216.00	246.00	7073.00	44.00	.00	.00	.00	.00	6.00	.00	6.00	.00	.00	1.00	.00	.00	.00	1.00	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

UPPER SALT CREEK #2
CONTRACT NUMBER 66-405-25
CHICAGO, ILLINOIS

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
75.00	46.00	46.00	40.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
27.00	23.00	69.00	17.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
75.00	103.00	172.00	30.00	.00	.00	8.00	.00	8.00	.00	16.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
173.00	213.00	385.00	41.00	.00	5.00	.00	.00	.00	.00	5.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
351.00	578.00	963.00	55.00	.00	6.00	.00	.00	2.00	.00	8.00	1.00	.00	.00	.20	.00	.00	1.00	.00	.00
969.00	159.00	1122.00	14.00	.00	6.00	.00	.00	18.00	.00	26.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
1129.00	549.00	1671.00	41.00	.00	.00	.00	.00	26.00	.00	26.00	1.00	1.00	1.00	1.00	.00	.00	1.00	.00	.50
1665.00	218.00	1889.00	16.00	.00	.00	.00	.00	9.50	18.50	28.00	1.00	.00	.50	.50	.00	.00	1.00	.00	.00
1903.00	495.00	2384.00	36.00	.00	.00	.00	.00	6.00	11.00	17.00	1.00	.00	.00	.10	.00	.00	1.00	.00	.10
2406.00	622.00	3006.00	51.00	.00	.00	.00	.00	9.00	.00	9.00	.00	1.00	.10	.20	.00	.00	1.00	.00	.00
3028.00	104.00	3110.00	5.00	.00	13.00	.00	.00	.00	.00	13.00	.00	.50	.00	.00	.00	.00	1.00	.00	.00
3132.00	570.00	3660.00	39.00	.00	.00	.00	.00	5.00	.00	5.00	.00	.50	.00	.00	.60	.00	1.00	.00	.00
3710.00	411.00	4091.00	31.00	.00	.00	.00	.00	10.00	7.00	17.00	1.00	.00	.00	.30	.00	.00	1.00	.00	.00
4129.00	513.00	4604.00	35.00	.00	.00	.00	.00	8.00	.00	8.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
4650.00	368.00	4972.00	25.00	.00	.00	.00	.00	8.00	7.00	15.00	1.00	.00	.00	.70	.00	.00	.00	.00	.00
5303.00	341.00	5313.00	24.00	.00	.00	.00	.00	10.00	.00	10.00	1.00	.00	.00	.00	.00	.00	.00	.00	.80

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-2S
CHICAGO, ILLINOIS

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
4681.00	20.00	20.00	10.00	.00	6.00	.00	.00	24.00	.00	30.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
4701.00	84.00	104.00	28.00	.00	.00	8.00	.00	3.00	1.00	12.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
4785.00	164.00	268.00	30.00	.00	2.00	.00	.00	8.00	.00	10.00	1.00	.00	.00	.50	.00	.00	.00	.00	.00
4949.00	120.00	388.00	23.00	.00	15.00	.00	.00	2.00	.00	17.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
5069.00	138.00	526.00	31.00	.00	.00	.00	.00	9.00	.00	9.00	1.00	.00	.00	1.00	.00	.00	1.00	.00	.00
5207.00	152.00	678.00	22.00	.00	.00	.00	.00	1.00	.00	1.00	1.00	.00	.00	.40	.00	.00	1.00	.00	.00
5359.00	164.00	842.00	31.00	.00	.00	.00	.00	1.00	8.00	9.00	1.00	.00	.00	.20	.00	.00	.00	.00	.00
5523.00	268.00	1110.00	36.00	.00	.00	.00	.00	3.00	1.00	4.00	1.00	.00	.00	.70	.00	.00	1.00	.00	.00
5791.00	120.00	1230.00	14.00	.00	.00	.00	.00	2.00	24.00	26.00	.20	1.00	.00	.40	.00	.00	.00	.00	.00
62.00	107.00	1337.00	13.00	.00	.00	.00	.00	27.00	.00	27.00	.50	.00	.50	.00	.00	.00	.00	.00	.00
169.00	80.00	1417.00	17.00	.00	7.00	16.00	.00	.00	.00	23.00	.90	.00	.10	.00	.00	.00	1.00	.00	.00
249.00	164.00	1581.00	30.50	.00	.00	5.50	.00	4.00	.00	9.50	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
413.00	200.00	1781.00	29.00	.00	.00	.00	.00	8.00	.00	8.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
613.00	112.00	1893.00	20.00	.00	.00	4.00	.00	2.00	6.00	12.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
725.00	260.00	2153.00	29.00	.00	.00	.00	.00	3.00	.00	3.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
985.00	324.00	2477.00	40.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
1309.00	252.00	2729.00	27.00	.00	.00	.00	.00	5.00	8.00	13.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
1561.00	300.00	3029.00	34.50	.00	.00	.00	.00	5.50	.00	5.50	1.00	.00	.20	.00	.00	.00	.80	.00	.00
1861.00	280.00	3309.00	31.00	.00	.00	1.00	.00	.00	8.00	9.00	1.00	.00	.16	.00	.00	.00	.96	.00	.00
2141.00	376.00	3685.00	38.00	.00	1.00	1.00	.00	.00	.00	2.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-2S
CHICAGO, ILLINOIS

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
2517.00	212.00	3897.00	24.00	.00	.00	3.00	.00	.00	13.00	16.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
2729.00	400.00	4297.00	37.00	.00	.00	3.00	.00	.00	.00	3.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
3129.00	288.00	4585.00	38.50	.00	.00	.00	.00	1.50	.00	1.50	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
3417.00	141.00	4726.00	24.00	.00	.00	.00	.00	.00	16.00	16.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
3558.00	80.00	4806.00	15.00	4.00	.00	.00	.00	5.00	16.00	25.00	.50	.50	.00	.00	.00	.00	1.00	.00	.00
3638.00	168.00	4974.00	32.00	.00	.00	.00	.00	8.00	.00	8.00	1.00	.30	.00	.00	.00	.00	1.00	.00	.00
3806.00	292.00	5266.00	37.00	.00	.00	.00	.00	3.00	.00	3.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
4098.00	316.00	5582.00	36.50	.00	.00	.00	.00	3.50	.00	3.50	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
4414.00	256.00	5838.00	31.00	.00	.00	4.00	.00	5.00	.00	9.00	1.00	.15	.15	.00	.00	.00	1.00	.00	.00

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON OUTBOUND
WASHINGTON, D.C.

				DOWNHOURS - HOURS/WEEK BY CAUSE							RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK								
STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
7050.57	67.00	67.00	78.49	.00	.00	.00	.33	9.68	.00	10.01	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
6983.57	46.19	113.19	27.28	.50	3.00	.70	.00	2.52	.00	6.72	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
6937.38	174.89	288.08	83.68	.58	.58	2.42	1.42	3.57	.25	8.82	.00	1.00	.00	.00	.00	.00	.00	.00	.00
6762.49	51.42	339.50	21.65	.00	.00	.00	.25	5.10	.00	5.35	.00	.00	1.00	1.00	.00	.00	.00	1.00	1.00
6711.07	213.94	553.44	69.83	1.50	.75	.00	.25	1.17	.00	3.67	1.00	.00	1.00	1.00	.00	.00	1.00	.00	.00
6497.13	54.37	607.81	23.34	.00	.00	.33	1.00	1.58	.25	3.16	1.00	.00	1.00	1.00	.00	.00	1.00	1.00	.00
6442.76	2.47	610.28	7.25	.00	.00	.25	.00	.00	.00	.25	1.00	1.00	.00	.00	.00	.00	1.00	1.00	.00
6440.29	91.74	702.02	37.15	4.00	.00	1.10	.00	6.00	.25	11.35	1.00	1.00	1.00	1.00	.00	.00	1.00	.00	.00
6348.55	133.57	835.57	77.55	3.20	3.00	.00	.00	10.75	.00	16.95	1.00	.00	1.00	1.00	.00	.00	1.00	1.00	.00
6214.98	261.95	1097.52	97.42	.00	.00	.00	1.00	9.08	.50	10.58	1.00	.00	1.00	1.00	.00	.00	1.00	.00	1.00
5953.03	293.27	1390.79	95.76	5.33	.25	.50	.33	8.08	.25	14.74	1.00	.00	1.00	1.00	.00	.00	1.00	.00	1.00
5659.76	17.47	1408.25	16.92	.00	.00	.00	.00	.33	.25	.58	1.00	.00	1.00	1.00	.00	.00	1.00	.00	.00

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
~~CONTRACT NUMBER~~ 1F0021
F2A PENTAGON INBOUND
WASHINGTON, D.C.

				DOWNHOURS - HOURS/WEEK BY CAUSE							RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK								
STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
7141.90	7.50	7.50	9.50	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
7134.40	6.80	14.30	8.28	.00	.22	1.00	.00	.00	.00	1.22	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
7127.60	24.96	39.26	38.11	.22	.67	.00	.00	.00	.00	.89	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
7102.64	2.42	41.68	8.40	1.60	.00	.00	.00	.00	.00	1.60	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
7100.22	17.21	58.89	28.50	11.50	2.00	2.30	.00	4.00	.00	19.80	1.00	1.00	.00	.00	.00	.00	1.00	.00	.00
7083.01	39.45	98.34	38.20	.00	.00	.00	.00	2.80	.00	2.80	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
7043.56	61.96	160.30	38.00	.00	.00	.00	.00	4.50	.00	4.50	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
6981.60	38.30	198.60	22.70	.00	1.90	.00	.00	.90	.00	2.80	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
6943.30	49.63	248.23	26.68	4.60	.00	.00	.00	2.20	.00	6.80	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
6893.67	41.07	289.30	38.60	1.00	.00	1.00	.30	.10	.00	2.40	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
6852.60	47.14	336.44	38.42	.75	.92	.00	.00	4.91	.00	6.58	1.00	1.00	.00	.00	.00	.00	1.00	.00	1.00
6805.46	146.66	483.10	79.95	2.75	.00	1.25	.00	16.80	.25	21.05	.00	1.00	.00	.00	.00	.00	.00	.00	1.00
6658.80	189.84	672.94	72.42	1.30	.00	.50	.53	1.75	.00	4.08	.00	1.00	1.00	.00	.00	.00	.00	.00	1.00
6468.96	167.03	839.97	72.05	5.70	1.00	5.00	.00	5.25	.00	16.95	.00	1.00	1.00	1.00	.00	.00	.00	1.00	1.00
6301.93	69.22	909.19	44.55	.00	.00	.00	.00	4.75	.20	4.95	.00	1.00	1.00	1.00	.00	.00	.00	1.00	1.00
6232.71	104.07	1013.26	61.77	.00	.20	1.33	.00	8.20	.00	9.73	1.00	1.00	1.00	1.00	.00	.00	1.00	1.00	1.00
6128.64	27.17	1040.43	17.50	.00	.00	.00	.00	1.00	.00	1.00	1.00	.00	1.00	1.00	.00	.00	1.00	1.00	1.00
6101.47	2.51	1042.94	6.50	.00	.00	.50	.00	2.00	.00	2.50	1.00	.00	1.00	1.00	.00	.00	1.00	1.00	1.00
6098.96	106.37	1149.31	63.03	1.80	.00	8.00	2.75	19.42	.50	32.47	1.00	.00	1.00	1.00	.00	.00	1.00	1.00	1.00
5992.59	170.31	1319.62	84.90	1.20	1.00	1.80	3.05	2.35	.20	9.60	1.00	1.00	1.00	1.00	.00	.00	1.00	1.00	1.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER

0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON INBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
5832.28	191.52	1511.14	89.40	4.70	2.90	2.00	.50	.80	.20	11.10	1.00	1.00	1.00	1.00	.00	.00	1.00	.00	.00

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE OUTBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
8605.69	69.89	69.89	54.08	.00	.00	.00	.00	1.92	.50	2.42	.20	.50	.30	.00	.00	.00	.20	.00	.00
8535.80	136.63	206.52	73.67	.00	5.50	2.83	1.42	9.08	.00	18.83	.10	.50	.30	.10	.00	.00	.10	.00	.00
8399.17	27.32	233.84	33.08	.00	.00	.42	.17	.33	.50	1.42	.00	.70	.20	.10	.00	.00	.00	.00	.00
8371.85	19.92	253.76	16.50	.00	.00	.00	.00	.00	.00	.00	.10	.70	.20	.00	.00	.00	.10	.00	.00
8351.93	202.84	456.60	62.00	1.50	.33	4.25	1.67	3.75	.50	12.00	.00	.80	.20	.00	.00	.00	.00	.00	.00
8149.09	154.17	610.77	48.67	4.00	.00	.33	.00	1.50	.00	5.83	.10	.60	.20	.00	.00	.10	.10	.00	.00
7994.92	265.54	876.31	87.42	.83	.00	1.00	.00	4.00	.75	6.58	.00	.50	.30	.10	.00	.10	.00	.00	.00
7729.38	178.93	1055.24	66.47	2.53	.00	15.92	.00	5.58	.00	24.03	.00	.70	.20	.10	.00	.00	.00	.00	.00
7550.45	311.93	1367.17	96.00	1.50	4.17	2.08	.00	4.75	.00	12.50	.00	.60	.30	.10	.00	.00	.00	.00	.00
7238.52	280.90	1648.07	87.58	.50	.75	.00	.41	.75	.50	2.41	.00	.50	.30	.20	.00	.00	.00	.00	.00
6924.85	269.76	1917.83	62.25	.75	.00	3.50	1.33	.17	.00	5.75	.00	.80	.20	.00	.00	.00	.00	.00	.00
6655.09	324.66	2242.49	65.84	.00	1.00	1.08	4.08	3.25	.25	9.66	.00	.70	.20	.10	.00	.00	.00	.00	.00
6330.43	324.53	2567.02	70.58	.00	1.17	.00	.42	1.33	.00	2.92	.00	.50	.30	.20	.00	.00	.00	.00	.00
6005.90	244.58	2811.60	75.84	5.33	.50	.00	2.83	7.50	.50	16.66	.40	.40	.10	.10	.00	.00	.40	.00	.00
5761.32	52.20	2863.80	42.25	5.17	3.58	.00	.42	1.58	.50	11.25	.60	.10	.20	.10	.00	.00	.60	.00	.00
5709.12	74.40	2938.20	31.25	5.00	3.00	.00	.50	5.25	.00	13.75	.90	.00	.10	.00	.00	.00	.90	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE INBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
6613.53	17.31	17.31	14.92	.00	.00	1.00	.00	1.58	.00	2.58	.00	1.00	1.00	1.00	.00	.00	.00	.00	.00
8596.22	84.73	102.04	75.91	.00	.00	2.17	.00	8.42	.00	10.59	.30	1.00	.50	.20	.00	.00	.20	.00	.00
6457.94	37.27	139.31	26.09	.00	.00	2.00	4.08	2.58	.25	8.91	.50	.60	.30	.00	.00	.00	.40	.00	.00
6420.67	188.24	327.55	65.50	1.25	.00	4.67	2.58	4.25	.25	13.00	1.00	.50	.40	.50	.00	.00	.70	.00	.00
8232.43	194.61	522.16	66.25	6.00	1.83	.25	.91	2.75	.50	12.24	.80	.40	.30	.20	.00	.30	.80	.00	.00
8037.82	164.88	687.04	55.42	.00	.25	.00	.33	7.50	.00	8.08	.80	.20	.40	.90	.00	.30	.80	.00	.00
7872.94	306.93	993.97	103.83	.00	.00	3.50	.75	2.92	.50	7.67	.70	.20	.50	.50	.00	.10	.70	.20	.00
7566.01	287.49	1281.46	99.33	.00	.00	1.00	.00	7.67	.50	9.17	.50	.40	.60	.70	.00	.00	.50	.00	.00
7278.52	300.15	1581.61	97.75	.00	.00	.00	1.67	8.58	.50	10.75	.30	.60	.80	.80	.00	.00	.30	.00	.00
6978.37	98.05	1679.66	64.82	.00	.00	1.00	.75	4.93	1.50	8.18	.20	.80	.50	.10	.00	.00	.20	.00	.10
6660.32	236.32	1915.98	89.83	.00	3.00	.42	.00	6.00	1.25	10.67	.40	.70	.60	.20	.00	.00	.40	.40	.20
6644.00	223.54	2139.52	96.92	.00	.00	1.50	1.00	9.08	.00	11.56	.40	.70	.60	.40	.00	.00	.40	.00	.50
6426.12	252.05	2391.57	82.49	.00	.00	1.42	2.17	3.92	.00	7.51	.40	.80	.50	.30	.00	.00	.40	.00	.60
6174.07	169.07	2560.64	80.58	1.58	.00	1.17	2.00	7.67	.00	12.42	.10	.90	.60	.80	.00	.00	.10	.60	1.00
6005.00	34.74	2595.38	38.16	.67	.00	.00	.00	3.67	.00	4.34	.70	.40	.80	.90	.00	.00	.70	.00	.50
5970.26	249.63	2645.01	119.07	2.18	.00	.75	.58	11.17	.00	14.68	.90	.30	.80	.90	.00	.00	.80	.00	.00
5720.63	89.66	2934.87	51.17	.00	.00	.33	.00	1.25	.25	1.83	1.00	.00	.30	.90	.00	.00	1.00	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B NORTH OUTBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
1352.00	16.00	16.00	39.00	.00	.00	.00	.00	.00	.00	.00	.50	.10	.40	.00	.00	.00	.50	.00	.00
1334.00	21.00	39.00	38.90	.00	.00	.00	3.06	3.00	.00	6.06	.50	.10	.40	.00	.00	.00	.50	.00	.00
1313.00	101.00	140.00	74.30	.00	.00	.00	1.00	.67	.00	1.67	.50	.10	.40	.00	.00	.00	.50	.00	.00
1212.00	142.00	282.00	79.40	9.65	.00	.00	.00	.00	6.92	16.57	.30	.20	.40	.10	.00	.00	.30	.00	.00
1070.00	84.00	366.00	74.80	9.33	.00	.00	.00	8.33	.00	17.66	.40	.30	.30	.00	.00	.00	.40	.20	.20
966.00	52.00	418.00	41.30	.00	.00	.00	.00	2.17	.00	2.17	.80	.00	.10	.00	.00	.10	.80	.20	.00
934.00	82.00	500.00	77.80	1.50	.00	.00	.00	6.67	.00	8.17	.80	.00	.20	.00	.00	.00	.80	.10	.00
852.00	105.00	605.00	95.80	5.25	.00	.00	.00	2.50	.00	7.75	.70	.00	.30	.00	.00	.00	.70	.10	.10
747.00	31.00	636.00	44.70	2.42	.00	.00	.00	9.92	.00	12.34	.70	.20	.00	.00	.00	.10	.70	.10	.00
716.00	73.00	709.00	62.60	.00	.00	.00	.00	3.91	.00	3.91	.70	.10	.20	.00	.00	.00	.70	.10	.10
643.00	24.00	733.00	41.80	.00	.00	.00	.00	7.67	.50	8.17	.40	.00	.60	.00	.00	.00	.40	.10	.00
619.00	67.00	800.00	48.30	7.08	.00	.00	.00	1.67	.00	8.75	.60	.10	.30	.00	.00	.00	.60	.10	.00
552.00	74.00	874.00	49.10	1.50	.00	.00	5.50	.92	.00	7.92	.60	.10	.30	.00	.00	.00	.60	.10	.00
478.00	76.00	950.00	45.40	1.17	.00	.00	.00	3.08	7.33	11.58	.50	.20	.30	.30	.60	.00	.50	.10	.00
402.00	25.00	975.00	19.00	.00	.00	.00	.00	.00	.00	.00	.50	.10	.40	.00	.00	.00	.50	.10	.00

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B NORTH INBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
1353.00	32.00	32.00	55.00	.00	.00	.00	.00	1.00	.00	1.00	.50	.00	.40	.10	.00	.00	.50	.00	1.00
1326.00	143.00	175.00	65.60	.00	.00	.00	.00	6.42	.00	6.42	.50	.10	.40	.10	.00	.00	.50	.00	.50
1183.00	109.00	284.00	77.20	.00	.00	.00	.00	3.33	.00	3.33	.50	.00	.40	.10	.00	.00	.50	.00	1.00
1074.00	69.00	353.00	49.10	.00	.00	.00	.00	6.58	.83	7.41	.10	.20	.70	.00	.00	.00	.10	.20	.50
1005.00	81.00	434.00	58.50	6.25	.00	.00	.00	1.75	.00	8.00	.00	.80	.00	.00	.00	.10	.00	.10	1.00
924.00	32.00	466.00	64.80	.00	.00	.00	.00	11.20	.00	11.20	.00	.90	.00	.00	.00	.00	.00	.10	1.00
892.00	55.00	521.00	61.50	1.25	.00	.00	.00	3.90	2.58	7.73	.00	1.00	.00	.00	.00	.00	.00	.50	.50
837.00	81.00	602.00	62.20	1.00	.00	.00	.60	2.15	.00	3.75	.00	1.00	.00	.00	.00	.00	.00	.20	.10
756.00	136.00	738.00	92.20	2.50	.00	.00	.75	.00	.00	3.25	.00	1.00	.00	.00	.00	.00	.00	.10	.00
620.00	112.00	850.00	60.70	3.60	.00	.00	.00	.00	.00	3.80	.00	1.00	.00	.00	.00	.00	.00	.00	.00
508.00	98.00	946.00	58.10	.00	.00	.00	.00	4.65	1.75	6.40	.20	.80	.00	.00	.00	.00	.20	.10	.00
410.00	27.00	975.00	24.50	.00	.00	.00	.00	.00	3.00	3.00	.20	.60	.20	.00	.00	.00	.20	.10	.00

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B SOUTH OUTBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
3973.00	7.50	7.50	6.60	.92	.00	.00	.00	8.00	.50	9.42	.00	.00	1.00	.00	.00	.00	.00	.00	.00
3965.50	19.00	26.50	25.20	1.57	.00	.00	.00	13.25	.00	14.82	.10	.00	.90	.00	.00	.00	.10	.00	.00
3946.50	16.00	42.50	18.50	.00	.00	.00	1.50	4.00	.00	5.50	.20	.00	.80	.00	.00	.00	.20	.00	.00
3930.50	36.50	79.00	31.00	.00	.00	.00	.00	2.00	.00	2.00	.30	.00	.70	.00	.00	.00	.30	.20	.00
3894.00	56.00	135.00	51.50	8.50	.00	.00	3.00	1.00	.00	12.50	.60	.00	.40	.00	.00	.00	.50	.00	.00
3838.00	60.00	195.00	57.40	12.30	.00	.00	.00	7.80	.00	20.10	.60	.00	.40	.00	.00	.00	.50	.00	.00
3778.00	82.00	277.00	61.40	7.00	.00	.00	2.00	7.10	.00	16.10	.80	.00	.20	.00	.00	.00	.80	.00	.00
3696.00	76.00	353.00	78.60	19.60	.33	.00	.00	5.00	.00	24.93	.70	.00	.30	.00	.00	.00	.70	.00	.20
3620.00	66.00	419.00	59.70	.33	.00	.00	.00	11.50	.00	11.83	.60	.00	.40	.00	.00	.00	.60	.00	.00
3554.00	11.50	430.50	10.00	6.00	.00	.00	.00	2.30	.00	8.30	.60	.00	.40	.00	.00	.00	.60	.00	.00
3542.50	16.50	449.00	25.70	.00	3.00	.00	.00	.00	.00	3.00	.50	.00	.50	.00	.00	.00	.50	.00	.00
3524.00	61.00	510.00	62.10	.67	4.65	.00	.58	1.50	.00	7.40	.60	.00	.30	.10	.00	.00	.60	.00	.00
3463.00	69.00	579.00	68.70	7.83	.00	.00	.00	1.00	.00	8.83	.70	.00	.20	.10	.00	.00	.70	.60	.40
3394.00	17.00	596.00	16.10	6.50	.00	.00	.00	.90	.00	7.40	.70	.00	.30	.00	.00	.00	.70	.60	.00
3377.00	35.50	631.50	53.70	5.25	.00	.00	3.58	.00	.00	8.83	.70	.00	.30	.00	.00	.00	.70	.00	.00
3341.50	72.50	704.00	65.50	1.25	11.00	.00	.00	7.75	.00	20.00	.60	.00	.30	.00	.10	.00	.60	.00	.50
3269.00	100.50	804.50	77.70	.00	1.00	.00	.00	8.83	.00	9.83	.60	.00	.30	.00	.10	.00	.60	.00	1.00
3168.50	53.50	858.00	52.00	.00	2.50	.00	14.50	1.00	.00	18.00	.60	.00	.20	.00	.20	.00	.60	.00	1.00
3115.00	101.50	959.50	68.50	6.33	2.50	.00	7.18	3.00	.00	19.01	.70	.20	.00	.00	.10	.00	.70	.00	.50
3013.50	125.50	1085.00	126.80	.00	.00	.00	3.33	7.83	.00	11.16	.50	.30	.10	.10	.00	.00	.50	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1FOU12
F1E SOUTH OUTBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
2868.00	124.00	1209.00	86.70	3.00	8.50	.00	1.75	3.00	.00	16.25	.50	.30	.10	.10	.00	.00	.50	.00	.00
2764.00	97.00	1306.00	66.50	2.00	2.00	.00	2.50	3.00	.00	9.50	.50	.30	.20	.00	.00	.00	.50	.00	1.00
2667.00	96.00	1404.00	68.70	14.50	.00	.00	.50	2.33	.00	17.33	.50	.10	.30	.10	.00	.00	.50	.00	1.00
2570.00	125.50	1529.50	83.40	5.42	1.00	.00	.00	5.67	.00	12.09	.50	.10	.30	.10	.00	.00	.50	.00	1.00
2444.50	129.50	1659.00	84.70	.00	2.25	.00	.00	6.60	.00	10.85	.40	.20	.20	.20	.00	.00	.40	.00	.50

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1FC012
F1B SOUTH INBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
3971.00	72.00	72.00	64.00	.00	.00	.00	.00	7.50	.00	7.50	.50	.10	.20	.20	.00	.00	.50	.20	.00
3899.00	67.00	139.00	73.90	.00	.00	.00	18.42	5.73	.00	24.15	.50	.00	.30	.20	.00	.00	.50	.80	.00
3832.00	113.00	252.00	82.00	.00	.00	.00	.00	5.50	.00	5.50	.70	.00	.20	.10	.00	.00	.70	.50	.00
3719.00	146.00	398.00	76.10	.58	.00	.00	.00	6.00	1.33	9.91	.70	.10	.20	.00	.00	.00	.70	.10	.00
3573.00	170.00	568.00	85.60	.00	.00	.00	.00	1.92	.00	1.92	.60	.00	.20	.00	.00	.00	.80	.00	.00
3403.00	93.00	661.00	54.40	.50	.25	.00	.00	1.33	.00	2.08	.70	.30	.00	.00	.00	.00	.70	.00	1.00
3310.00	141.00	802.00	83.00	.00	.50	.00	1.50	3.00	.00	5.00	.60	.30	.00	.00	.10	.00	.60	.00	.00
3169.00	162.00	964.00	89.20	2.83	.50	.00	.00	1.00	.00	4.33	.50	.40	.10	.00	.00	.00	.60	.00	1.00
3007.00	150.00	1114.00	97.00	.00	.00	.00	.00	2.00	.00	2.00	.70	.20	.10	.00	.00	.00	.70	.00	.50
2857.00	133.00	1247.00	91.00	1.00	.00	.00	.00	.00	.00	1.00	.50	.30	.10	.10	.00	.00	.50	.00	.70
2724.00	129.00	1376.00	80.30	1.50	.25	.00	1.10	.83	.00	3.68	.50	.20	.10	.20	.00	.00	.50	.00	.50
2595.00	109.00	1485.00	73.40	6.33	.00	.00	2.00	.75	5.00	14.08	.50	.10	.30	.10	.00	.00	.50	.00	.40
2486.00	97.00	1582.00	70.30	3.17	.00	.00	5.00	3.50	.00	11.67	.50	.20	.20	.10	.00	.00	.50	.00	.50
2389.00	72.00	1654.00	62.30	1.17	.00	.00	2.00	1.00	.00	4.17	.50	.20	.20	.10	.00	.00	.50	.00	.40

Appendix A-2. (Continued)

PROGRESS AND PRODUCTION

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 100091
D-9 SOUTH INBOUND
WASHINGTON, D.C.

STATION AT START OF WEEK	TUNNEL RATE FT/WK	CUMUL. FEET TO DATE	PROD HRS IN WEEK	DOWNHOURS - HOURS/WEEK BY CAUSE: SHIELD	EXCAV EQUIP	CONVEYOR	MUCK TRANS	MISC	ADMIN	TOTAL DOWN HOURS	RELATIVE FREQUENCY OF SOIL TYPE DURING THE WEEK: I	II	III	IV	V	VI	VII	VIII	RUNNING WATER*
22168.00	28.00	28.00	94.75	.00	.00	.00	1.00	.00	.25	1.25	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
22140.00	84.90	112.90	105.00	.00	4.00	.60	.00	8.00	.00	12.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
22079.00	105.00	217.90	111.33	.00	4.17	.00	2.00	2.00	.00	8.17	.80	.00	.00	.00	.20	.00	.80	.00	.00
21974.00	83.00	300.90	106.00	1.00	4.00	.00	11.00	8.00	.00	24.00	.90	.00	.00	.00	.10	.00	.90	.00	.00
21891.00	78.00	378.90	93.00	.00	.00	.00	14.00	.00	.00	14.00	1.00	.00	.00	.00	.00	.00	1.00	.10	.30
21813.00	123.00	501.90	110.00	.00	.00	.00	21.00	4.00	.00	25.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.30
21690.00	106.00	607.90	110.00	7.50	5.50	.00	2.00	5.00	.00	20.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.10
21584.00	92.00	699.90	107.00	.00	.00	.00	.00	8.75	.00	8.75	1.00	.00	.00	.00	.00	.00	1.00	.00	.00
21492.00	25.00	724.90	30.00	.00	.00	.00	8.00	.00	.00	8.00	1.00	.00	.00	.00	.00	.00	1.00	.00	.00

KEY FOR SOIL TYPES
I - SILT AND CLAY
II - CLAY AND SAND
III - SAND AND GRAVEL
IV - COBBLES AND BOULDERS
V - CEMENTED GROUND
VI - PEAT AND TRASH
VII - COHESIVE GROUND
VIII - RUNNING GROUND

*KEY TO VALUES FOR RUNNING WATER
0 = DRY
.25 = MOIST
.50 = WET
.75 = RUNNING WATER
1 = FLOODED

Appendix A-2. (Continued)

Appendix A-3

Rate of advance calculations vs. measured rate for each data set of each tunnel.

The calculation procedure includes the estimate of the learning curve exponent, equation (6.1), the intercept, equation (6.2) and their substitution in the RoA equation (6.3).

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	15.00	1.00	.75	9.93	1.50	30.15	26.22	30.15	26.22	8.00	8.00
2	47.50	1.12	.75	9.93	1.50	43.10	42.31	73.25	68.53	32.00	40.00
3	235.00	1.00	.75	9.93	1.50	145.82	141.14	219.07	209.67	110.00	150.00
4	332.50	1.03	.75	9.93	1.50	61.73	61.62	280.80	271.28	41.00	191.00
5	557.50	1.02	.73	9.93	1.50	118.63	118.17	399.44	389.46	111.00	302.00
6	680.00	1.03	.73	9.93	1.50	63.48	63.43	462.91	452.89	56.00	358.00
7	825.00	1.01	.77	9.93	1.50	69.75	69.71	532.66	522.60	54.00	412.00
8	1085.00	1.02	.77	9.93	1.50	118.20	118.37	650.87	640.67	94.00	506.00
9	1377.50	1.00	.76	9.93	1.50	119.01	118.90	769.87	759.57	94.00	600.00
10	1502.50	1.12	.76	9.93	1.50	54.26	54.26	824.14	813.83	84.00	684.00
11	1657.50	1.15	.76	9.93	1.50	67.14	67.13	891.28	880.96	77.00	761.00
12	1850.00	1.04	.76	9.93	1.50	73.02	73.01	964.30	953.96	90.00	851.00
13	1960.00	1.38	.79	9.93	1.50	57.28	57.28	1021.58	1011.24	50.00	901.00
14	2050.00	1.03	.79	9.93	1.50	34.30	34.30	1055.88	1045.54	112.00	1013.00
15	2300.00	1.05	.79	9.93	1.50	95.02	95.00	1150.90	1140.54	86.00	1099.00
16	2557.50	1.06	.79	9.93	1.50	95.92	95.91	1246.82	1236.45	82.00	1181.00
17	2857.50	1.02	.79	9.93	1.50	104.19	104.17	1351.02	1340.62	95.00	1276.00
18	3102.50	1.05	.76	9.93	1.50	81.35	81.34	1432.36	1421.96	100.00	1376.00
19	3340.00	1.08	.76	9.93	1.50	79.32	79.31	1511.68	1501.27	88.00	1464.00
20	3557.50	1.02	.90	9.93	1.50	94.33	94.32	1606.01	1595.59	94.00	1558.00

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
21	3855.00	1.04	.76	9.93	1.50	79.16	79.17	1685.19	1674.76	95.00	1653.00
22	4102.50	1.07	.76	9.93	1.50	76.63	76.62	1761.81	1751.39	92.00	1745.00
23	4297.50	1.09	.76	9.93	1.50	60.75	60.74	1822.56	1812.13	83.00	1828.00
24	4345.00	2.16	.76	9.93	1.50	29.04	29.04	1851.60	1841.17	41.00	1869.00
25	4425.00	1.01	.78	9.93	1.50	23.28	23.28	1874.87	1864.45	56.00	1925.00

Appendix A-3. Rate of Advance Calculations.

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	20.00	1.04	.75	9.93	1.50	39.25	34.45	39.25	34.45	32.00	32.00
2	52.50	1.08	.75	9.93	1.50	41.41	40.90	80.66	75.35	34.00	66.00
3	175.00	1.27	.75	9.93	1.50	134.94	132.42	215.60	207.77	76.00	142.00
4	335.00	1.15	.75	9.93	1.50	125.79	125.35	341.40	332.82	89.00	231.00
5	555.00	1.02	.73	9.93	1.50	128.52	128.06	469.92	460.87	113.00	344.00
6	792.50	1.00	.77	9.93	1.50	127.47	127.24	597.39	588.11	102.00	446.00
7	1162.50	1.01	.77	9.93	1.50	180.39	180.31	777.78	768.11	112.00	558.00
8	1350.00	1.02	.76	9.93	1.50	84.87	84.84	862.65	852.96	60.00	618.00
9	1487.50	1.01	.76	9.93	1.50	59.31	59.31	921.96	912.26	63.00	681.00
10	1515.50	1.09	.76	9.93	1.50	12.85	12.62	934.81	924.66	10.00	691.00
11	1695.00	1.06	.76	9.93	1.50	78.86	79.37	1013.67	1003.95	84.00	775.00
12	1870.00	1.07	.76	9.93	1.50	75.65	75.64	1089.32	1079.59	93.00	868.00
13	1935.00	1.66	.79	9.93	1.50	44.84	44.84	1134.16	1124.43	59.00	927.00
14	1987.50	3.49	.79	9.93	1.50	75.62	32.34	1209.78	1156.77	28.00	955.00
15	2167.50	1.71	.79	9.93	1.50	86.20	86.20	1295.98	1242.97	66.00	1021.00
16	2495.00	1.02	.79	9.93	1.50	132.86	132.82	1428.85	1375.79	104.00	1125.00
17	2577.50	1.53	.79	9.93	1.50	48.61	48.61	1477.45	1424.40	56.00	1181.00
18	2787.50	1.04	.79	9.93	1.50	82.31	82.30	1559.76	1506.70	101.00	1282.00
19	3080.00	1.02	.76	9.93	1.50	105.01	105.30	1664.78	1611.70	94.00	1376.00
20	3285.00	1.06	.76	9.93	1.50	74.81	74.81	1739.59	1686.50	95.00	1471.00

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
21	3510.00	1.08	.76	9.93	1.50	81.68	83.50	1821.26	1770.01	92.00	1563.00
22	3795.00	1.03	.90	9.93	1.50	115.00	114.99	1936.27	1885.00	95.00	1658.00
23	4120.00	1.02	.76	9.93	1.50	107.42	107.41	2043.68	1992.40	104.00	1762.00
24	4280.00	1.04	.76	9.93	1.50	52.88	52.88	2096.56	2045.26	108.00	1870.00
25	4390.00	1.00	.78	9.93	1.50	35.78	35.78	2132.34	2081.06	101.00	1971.00

Appendix A-3 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
RR/RL TUNNELS
BERKELEY, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	29.00	1.09	.88	10.77	.82	153.23	91.99	153.23	91.99	76.00	76.00
2	90.00	1.00	.88	10.77	.82	198.67	195.58	351.90	287.58	120.00	196.00
3	163.00	1.00	.88	10.77	.82	191.87	191.04	543.78	478.61	118.00	314.00
4	212.00	1.13	.88	10.77	.82	131.75	131.63	675.52	610.25	111.00	425.00
5	264.00	1.09	.88	10.77	.82	127.02	126.94	802.55	737.19	114.00	539.00
6	320.00	1.01	.88	10.77	.82	120.11	120.05	922.65	857.24	119.00	658.00
7	367.00	1.39	.88	10.77	.82	133.41	133.38	1056.06	990.62	80.00	738.00
8	443.00	1.00	.88	10.77	.82	149.42	149.36	1205.49	1139.97	118.00	856.00
9	529.00	1.00	.88	10.77	.82	161.53	161.46	1367.01	1301.44	120.00	976.00
10	616.00	1.01	.88	10.77	.82	158.79	158.75	1525.81	1460.18	118.00	1094.00
11	710.00	1.03	.88	10.77	.82	171.58	171.53	1697.39	1631.71	111.00	1205.00
12	771.00	1.02	.88	10.77	.82	101.58	101.57	1798.97	1733.29	78.00	1283.00
13	867.00	1.01	.88	10.77	.82	152.14	152.11	1951.10	1885.40	117.00	1400.00
14	944.00	1.04	.88	10.77	.82	136.96	136.95	2088.06	2022.35	113.00	1513.00
15	1016.00	1.14	.80	10.77	.82	118.18	118.17	2206.24	2140.52	99.00	1612.00
16	1090.00	1.01	.80	10.77	.82	117.97	117.96	2324.21	2258.47	119.00	1731.00
17	1157.00	1.02	.80	10.77	.82	82.06	82.06	2406.27	2340.53	94.00	1825.00
18	1225.00	1.00	.80	10.77	.82	93.28	94.65	2499.55	2435.19	96.00	1921.00
19	1297.00	1.00	.90	10.77	.82	99.46	99.46	2599.01	2534.64	120.00	2041.00
20	1374.00	1.00	.90	10.77	.82	127.35	127.34	2726.35	2661.98	119.00	2160.00

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
RR/RL TUNNELS
BERKELEY, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
21	1459.00	1.00	.90	10.77	.82	126.92	126.91	2853.27	2788.90	119.00	2279.00
22	1474.00	1.00	.90	10.77	.82	22.10	22.10	2875.37	2811.00	120.00	2399.00
23	1479.00	1.00	.90	10.77	.82	7.35	7.35	2882.72	2818.35	120.00	2519.00
24	1599.00	1.01	.66	10.77	.82	127.85	127.84	3010.58	2946.19	115.00	2634.00
25	1677.00	1.01	.66	10.77	.82	78.10	78.10	3088.68	3024.29	78.00	2712.00
26	1810.00	1.00	.66	10.77	.82	142.29	142.28	3230.97	3166.57	119.00	2831.00
27	1947.00	1.02	.66	10.77	.82	137.47	137.47	3368.44	3304.03	112.00	2943.00
28	2059.00	1.06	.66	10.77	.82	121.87	121.86	3490.31	3425.90	103.00	3046.00
29	2199.00	1.01	.66	10.77	.82	137.76	137.76	3628.07	3563.65	118.00	3164.00
30	2329.00	1.02	.66	10.77	.82	128.00	128.00	3756.08	3691.65	112.00	3276.00
31	2369.00	1.41	.66	10.77	.82	52.45	52.45	3808.53	3744.10	69.00	3345.00
32	2467.00	1.01	.90	10.77	.82	123.73	123.73	3932.26	3867.83	117.00	3462.00
33	2546.00	1.02	.90	10.77	.82	110.58	110.58	4042.83	3978.40	116.00	3578.00
34	2650.00	1.00	.90	10.77	.82	133.15	133.15	4175.99	4111.55	119.00	3697.00
35	2746.00	1.00	.90	10.77	.82	121.74	121.73	4297.72	4233.29	120.00	3817.00
36	2810.00	1.31	.90	10.77	.82	105.17	105.17	4402.89	4338.45	77.00	3894.00
37	2889.00	1.01	.90	10.77	.82	98.27	98.27	4501.16	4436.73	118.00	4012.00
38	2903.00	1.00	.90	10.77	.82	18.69	18.69	4519.86	4455.42	120.00	4132.00

Appendix A-3 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TR TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	47.43	1.01	.73	9.11	1.09	77.98	66.12	77.98	66.12	63.08	63.08
2	194.73	1.01	.75	9.11	1.09	128.04	124.20	206.02	190.32	114.84	177.92
3	362.07	1.01	.75	9.11	1.49	149.09	148.11	355.11	338.42	112.76	290.68
4	566.85	1.01	.76	9.11	1.49	155.81	155.27	510.93	493.69	115.59	406.27
5	696.74	1.07	.75	9.11	1.63	102.73	102.66	613.66	596.35	99.44	505.71
6	888.96	1.06	.73	9.11	1.49	123.71	123.58	737.37	719.93	99.37	605.08
7	1116.23	1.03	.75	9.11	1.49	135.36	135.24	872.74	855.17	102.36	707.44
8	1357.38	1.03	.75	9.11	1.49	132.08	132.00	1004.82	987.17	108.40	815.84
9	1463.21	1.00	.73	9.11	1.49	55.59	55.59	1060.41	1042.76	118.66	934.50
10	1515.49	1.12	.75	9.11	1.63	32.69	32.69	1093.11	1075.45	97.62	1032.12
11	1557.48	1.02	.75	9.11	1.63	34.54	34.54	1127.65	1109.99	103.95	1136.07

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TL TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	44.76	1.01	.77	9.59	.82	71.71	62.23	71.71	62.23	97.85	97.85
2	137.34	1.03	.79	9.59	.82	90.46	88.86	162.17	151.10	112.67	210.52
3	339.61	1.00	.81	9.59	.82	129.36	128.10	291.53	279.19	114.59	325.11
4	469.43	1.00	.75	9.59	1.49	170.18	169.73	461.71	448.92	93.00	418.11
5	529.31	1.01	.74	9.59	1.49	152.60	152.40	614.31	601.32	93.58	511.69
6	826.68	1.02	.76	9.59	1.49	179.88	178.57	793.19	779.99	111.70	623.39
7	1054.04	1.03	.75	9.59	1.49	191.68	191.51	984.88	971.50	102.59	725.98
8	1281.41	1.03	.75	9.59	1.49	181.42	181.31	1166.29	1152.81	105.10	831.09
9	1451.36	1.07	.77	9.59	1.51	139.24	138.21	1304.54	1291.02	92.24	923.32
10	1516.29	1.00	.75	9.59	1.49	46.47	46.47	1351.01	1337.49	116.50	1039.82
11	1551.29	1.00	.75	9.59	1.49	43.51	43.51	1394.52	1381.00	75.66	1115.48

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
SR TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	42.50	1.17	.83	9.59	1.09	83.56	73.02	83.56	73.02	55.42	55.42
2	165.10	1.00	.83	9.59	1.09	117.81	115.02	201.36	188.04	113.08	168.50
3	212.63	1.01	.83	9.59	1.09	38.18	38.14	239.54	226.18	44.24	212.74
4	325.03	1.04	.83	9.59	1.49	114.96	114.65	354.50	340.84	84.83	297.57
5	489.91	1.01	.86	9.59	1.49	151.06	150.68	505.56	491.52	113.08	410.65
6	654.75	1.03	.80	9.59	1.49	130.14	129.98	635.70	621.50	108.81	519.46
7	839.32	1.04	.79	9.59	1.49	134.80	134.67	770.50	756.17	100.83	620.29
8	1031.61	1.06	.85	9.59	1.49	143.36	143.27	913.86	899.44	91.23	711.52
9	1236.34	1.00	.83	9.59	1.49	134.26	134.19	1048.12	1033.63	117.00	828.52
10	1415.75	1.00	.83	9.59	1.49	112.59	112.55	1160.70	1146.19	95.42	923.94
11	1552.94	1.00	.85	9.59	1.54	153.42	153.40	1314.12	1299.58	84.08	1008.02

Appendix A-3 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
SL TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	29.93	1.00	.75	8.71	1.49	75.73	63.81	75.73	63.81	109.33	109.33
2	109.53	1.00	.75	8.71	1.49	105.35	102.53	181.09	166.44	116.16	225.49
3	209.45	1.04	.75	8.71	1.49	102.64	101.88	283.72	268.31	112.17	337.66
4	326.95	1.02	.75	8.71	1.49	99.36	99.30	383.08	367.32	112.42	450.08
5	386.93	1.02	.75	8.71	1.49	45.81	45.79	428.89	413.10	57.67	507.75
6	525.83	1.03	.75	8.71	1.49	98.81	98.64	527.70	511.74	108.50	616.25
7	639.23	1.05	.75	8.71	1.49	76.11	76.06	603.81	587.80	81.17	697.42
8	796.72	1.01	.75	8.71	1.49	95.24	95.15	699.05	682.96	105.58	803.00
9	851.61	1.04	.75	8.71	1.49	32.62	32.62	731.68	715.58	88.90	891.90
10	981.25	1.14	.75	8.71	1.49	81.11	81.08	812.79	796.66	92.08	983.98
11	1116.09	1.13	.75	8.71	1.49	80.22	80.20	893.02	876.86	98.42	1082.40
12	1295.74	1.02	.75	8.71	1.49	92.22	92.18	985.23	969.04	112.09	1194.49
13	1457.86	1.08	.75	8.71	1.36	76.52	76.50	1061.75	1045.54	83.95	1278.44
14	1565.19	1.01	.75	8.71	1.49	88.11	88.10	1149.86	1133.64	74.83	1353.27

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0051A
SL TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	85.00	1.02	.83	8.71	1.17	279.96	130.39	279.96	130.39	112.36	112.36
2	152.50	1.10	.80	8.71	1.17	138.03	137.19	417.99	267.58	94.08	206.44
3	220.00	1.09	.79	8.71	1.17	116.65	116.37	534.64	383.94	96.44	302.88
4	280.00	1.03	.79	8.71	1.17	87.49	87.40	622.13	471.34	78.36	381.24
5	350.00	1.01	.75	8.71	1.17	89.23	89.15	711.36	560.49	79.50	460.74
6	457.20	1.03	.76	8.71	1.17	129.00	128.83	840.36	689.32	106.03	566.77
7	564.70	1.02	.75	8.71	1.17	117.41	117.32	957.78	806.64	110.10	676.87
8	680.70	1.03	.83	8.71	1.17	142.61	142.51	1100.39	949.15	103.49	780.36
9	720.70	1.01	.83	8.71	1.17	75.17	75.17	1175.57	1024.72	49.46	829.82

BAY AREA RAPID TRANSIT
CONTRACT NUMBER 1S0051A
SR TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	27.46	1.00	.80	6.64	1.09	67.74	43.51	67.74	43.51	66.00	66.00
2	94.96	1.03	.74	8.84	1.09	80.86	78.73	148.60	122.24	110.25	176.25
3	137.46	1.09	.81	8.84	1.09	45.76	45.64	194.36	167.88	52.34	228.59
4	190.24	1.02	.89	8.84	1.63	78.21	78.05	272.57	245.93	74.67	303.26
5	277.46	1.04	.77	8.84	1.63	100.33	100.06	372.90	345.99	106.69	409.95
6	384.96	1.07	.81	8.84	1.63	118.09	117.94	490.99	463.83	100.64	510.59
7	477.46	1.01	.83	8.84	1.63	90.29	90.21	581.28	554.04	78.25	588.84
8	564.96	1.02	.89	8.84	1.63	86.15	86.10	667.43	640.14	73.26	662.10
9	687.46	1.01	.93	8.84	1.63	104.97	104.89	772.40	745.03	105.52	767.62
10	759.96	1.01	.86	8.84	1.63	33.65	33.65	806.05	778.68	37.75	805.37

Appendix A-3 (continued)

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	24.00	1.13	.72	6.92	1.50	28.59	23.99	28.59	23.99	25.50	25.50
2	39.00	1.07	.75	6.92	1.50	10.27	10.23	38.86	34.22	16.00	41.50
3	130.00	1.05	.77	6.92	1.50	49.84	48.60	88.70	82.82	44.00	85.50
4	210.00	1.04	.67	6.92	1.50	28.58	28.46	117.28	111.28	25.00	110.50
5	214.00	1.99	.67	6.92	1.50	2.46	2.46	119.74	113.74	3.00	113.50
6	242.00	1.92	.67	6.92	1.50	16.58	16.58	136.32	130.32	14.00	127.50
7	265.00	1.27	.75	6.92	1.50	9.82	9.82	146.14	140.14	18.00	145.50
8	280.00	1.01	.75	6.92	1.50	6.30	6.30	152.44	146.44	10.00	155.50
9	358.00	1.13	.71	6.92	1.50	24.48	24.46	176.92	170.89	30.00	185.50
10	410.00	1.20	.67	6.92	1.50	16.22	16.21	193.13	187.10	18.00	203.50
11	590.00	1.02	.67	6.92	1.50	43.63	43.52	236.76	230.62	40.00	243.50
12	704.00	1.11	.67	6.92	1.50	27.93	27.92	264.70	258.54	25.50	269.00
13	839.00	1.08	.64	6.92	1.50	28.14	28.13	292.84	286.66	28.00	297.00
14	1094.00	1.02	.75	6.92	1.50	55.60	55.53	348.44	342.19	38.00	335.00
15	1362.00	1.00	.75	6.92	1.50	52.89	52.84	401.32	395.03	38.00	373.00
16	1466.00	1.15	.85	6.92	1.50	25.60	25.60	426.92	420.63	16.50	389.50
17	1510.00	1.62	.92	6.92	1.50	16.21	16.21	443.14	436.84	12.00	401.50
18	1530.00	1.08	.89	6.92	1.50	4.73	4.73	447.86	441.57	12.00	413.50
19	1586.00	1.04	1.05	6.92	1.50	14.91	14.91	462.77	456.47	41.50	455.00
20	1665.00	1.08	.96	6.92	1.50	20.45	20.45	483.22	476.92	33.00	488.00

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
21	1922.00	1.02	.94	6.92	1.50	34.34	34.33	517.56	511.25	38.50	526.50
22	2002.00	1.06	.82	6.92	1.50	35.65	35.55	553.21	546.90	37.00	563.50
23	2075.00	1.04	.76	6.92	1.50	12.79	12.79	566.00	559.69	34.00	597.50
24	2239.00	1.02	.93	6.92	1.50	33.95	33.95	599.95	593.64	41.00	638.50
25	2274.00	1.36	.93	6.92	1.50	9.54	9.59	609.49	603.18	19.00	657.50
26	2330.00	1.31	.75	6.92	1.50	13.51	13.51	623.00	616.69	23.00	680.50
27	2513.00	1.05	.75	6.92	1.50	29.20	29.19	652.19	645.86	31.00	711.50
28	2933.00	1.00	.82	6.92	1.50	53.49	53.48	705.68	699.36	45.00	756.50
29	3041.00	1.02	.67	6.92	1.50	27.98	27.98	733.67	727.34	25.00	781.50
30	3349.00	1.03	.80	6.92	1.50	48.90	48.90	782.57	776.23	39.00	820.50
31	3625.00	1.01	.66	6.92	1.50	34.29	34.28	816.85	810.51	37.00	857.50
32	3953.00	1.05	.74	6.92	1.50	32.18	32.18	849.03	842.68	31.00	888.50
33	4229.00	1.00	.78	6.92	1.50	51.83	51.82	900.86	894.51	45.00	933.50
34	4445.00	1.05	.78	6.92	1.50	30.69	30.69	931.55	925.20	22.00	955.50
35	4725.00	1.00	.90	6.92	1.50	42.91	42.91	974.47	968.11	34.00	989.50
36	4877.00	1.08	.93	6.92	1.50	25.59	25.59	1000.06	993.70	23.50	1013.00
37	5177.00	1.01	.75	6.92	1.50	37.68	37.68	1037.74	1031.38	37.00	1050.00
38	5481.00	1.04	.75	6.92	1.50	38.33	38.32	1076.07	1069.70	37.00	1087.00
39	5881.00	1.00	.75	6.92	1.50	47.65	47.64	1123.71	1117.35	45.00	1132.00
40	6167.00	1.04	.84	6.92	1.50	38.71	38.71	1162.93	1156.06	33.50	1165.50

Appendix A-3 (continued)

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-2S
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
41	6345.00	1.00	1.02	6.92	1.50	27.88	27.88	1190.30	1183.93	31.00	1196.50
42	6445.00	1.08	1.02	6.92	1.50	16.71	16.71	1207.01	1200.64	30.00	1226.50
43	6457.00	1.14	1.02	6.92	1.50	8.46	8.46	1215.47	1209.10	25.00	1251.50
44	6519.00	1.70	.99	6.92	1.50	6.59	6.59	1222.05	1215.66	17.00	1268.50
45	6565.00	1.09	1.02	6.92	1.50	7.72	7.72	1229.77	1223.40	26.00	1294.50
46	6667.00	1.10	1.02	6.92	1.50	16.49	16.49	1246.26	1239.89	33.00	1327.50
47	6825.00	1.00	1.02	6.92	1.50	24.72	24.72	1270.98	1264.61	36.00	1363.50
48	7077.00	1.00	1.02	6.92	1.50	37.41	37.41	1308.39	1302.02	44.00	1407.50

UPPER SALT CREEK #2
CONTRACT NUMBER 68-405-2S
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	46.00	1.00	.75	6.29	1.63	23.48	19.63	23.48	19.63	40.00	40.00
2	69.00	1.00	.75	6.29	1.63	7.22	7.19	30.70	26.83	17.00	57.00
3	172.00	1.03	.75	6.29	1.63	26.24	25.85	56.94	52.68	30.00	87.00
4	385.00	1.02	.75	6.29	1.50	36.81	36.38	93.75	89.06	41.00	128.00
5	567.00	1.01	.73	6.29	1.50	71.18	70.12	164.93	159.19	55.00	183.00
6	1122.00	1.04	.75	6.29	1.50	17.76	17.75	182.69	176.94	14.00	197.00
7	1671.00	1.00	.69	6.29	1.50	49.21	49.06	231.90	226.01	41.00	238.00
8	1989.00	1.09	.77	6.29	1.50	21.85	21.85	253.75	247.85	16.00	254.00
9	2384.00	1.02	.74	6.29	1.50	41.89	41.95	295.65	289.70	36.00	290.00
10	3006.00	1.00	.75	6.29	1.50	47.95	47.90	343.59	337.60	51.00	341.00
11	3110.00	1.10	.79	6.29	1.50	9.00	9.00	352.60	346.60	5.00	346.00
12	3680.00	1.00	.79	6.29	1.50	43.27	43.25	395.87	389.85	39.00	385.00
13	4091.00	1.02	.72	6.29	1.50	27.42	27.41	423.29	417.27	31.00	416.00
14	4634.00	1.00	.75	6.29	1.50	33.89	33.88	457.17	451.14	35.00	451.00
15	4972.00	1.02	.90	6.29	1.50	25.46	25.45	482.63	476.60	25.00	476.00
16	5313.00	1.00	.88	6.29	1.50	24.78	24.78	507.41	501.38	24.00	500.00

Appendix A-3 (continued)

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	20.00	1.20	.75	5.77	1.63	22.59	19.15	22.59	19.15	10.00	10.00
2	104.00	1.05	.67	5.77	1.50	32.94	31.66	55.53	50.82	28.00	38.00
3	268.00	1.01	.82	5.77	1.53	53.20	52.42	108.73	103.23	30.00	68.00
4	369.00	1.10	.67	5.77	1.50	27.82	27.76	136.55	130.99	23.00	91.00
5	526.00	1.00	.67	5.77	1.50	26.15	26.11	162.70	157.10	31.00	122.00
6	675.00	1.00	.71	5.77	1.50	28.00	27.97	190.70	185.07	22.00	144.00
7	842.00	1.05	.85	5.77	1.50	35.24	35.21	225.95	220.28	31.00	175.00
8	1110.00	1.00	.66	5.77	1.50	41.03	40.97	266.97	261.25	36.00	211.00
9	1230.00	1.21	.90	5.77	1.50	24.28	24.27	291.25	285.53	14.00	225.00
10	1337.00	1.01	1.02	6.92	1.50	26.90	26.89	318.15	312.42	13.00	238.00
11	1417.00	1.15	.76	6.92	1.50	17.03	17.03	335.18	329.45	17.00	255.00
12	1561.00	1.01	.75	6.92	1.50	29.04	29.03	364.22	358.48	30.50	285.50
13	1781.00	1.00	.75	6.92	1.50	33.70	33.69	397.92	392.16	29.00	314.50
14	1897.00	1.07	.75	6.92	1.50	19.62	19.51	417.54	411.79	20.00	334.50
15	2157.00	1.00	.75	6.92	1.50	41.24	41.23	458.78	453.02	29.00	363.50
16	2477.00	1.00	.75	6.92	1.50	49.20	49.18	507.98	502.21	40.00	403.50
17	2720.00	1.03	.75	6.92	1.50	38.09	38.09	546.07	540.29	27.00	430.50
18	3029.00	1.00	.80	6.92	1.50	45.49	45.48	591.56	585.77	34.50	465.00
19	3309.00	1.03	.78	6.92	1.50	41.30	41.30	632.87	627.07	31.00	496.00
20	3655.00	1.00	.75	6.92	1.50	50.16	50.15	683.03	677.22	38.00	534.00

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
21	3897.00	1.07	.75	6.92	1.50	29.40	29.40	712.43	706.62	24.00	558.00
22	4297.00	1.00	.75	6.92	1.50	50.70	50.70	763.13	757.32	37.00	595.00
23	4565.00	1.00	.75	6.92	1.50	35.47	35.46	798.60	792.78	38.50	633.50
24	4726.00	1.12	.75	6.92	1.50	19.15	19.15	817.75	811.93	24.00	657.50
25	4806.00	1.23	.73	6.92	1.50	11.62	11.62	829.37	823.55	15.00	672.50
26	4974.00	1.00	.71	6.92	1.50	19.10	19.10	848.47	842.65	32.00	704.50
27	5266.00	1.00	.75	6.92	1.50	34.36	34.35	882.82	877.00	37.00	741.50
28	5567.00	1.00	.75	6.92	1.50	36.50	36.50	919.32	913.50	36.50	778.00
29	5938.00	1.01	.76	6.92	1.50	29.50	29.50	948.82	943.00	31.00	809.00

Appendix A-3 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	67.00	1.01	.66	10.40	1.36	94.67	84.01	94.67	84.01	78.49	78.49
2	113.19	1.06	.66	10.40	1.36	47.66	47.49	142.34	131.51	27.28	105.77
3	288.08	1.02	.88	10.40	1.36	187.64	185.59	329.98	317.09	83.68	189.45
4	339.50	1.00	.90	10.40	1.36	49.62	49.60	379.60	366.70	21.65	211.10
5	557.44	1.01	.79	10.40	1.36	165.88	165.36	545.48	532.06	69.83	280.93
6	607.81	1.02	.68	10.40	1.36	34.01	34.00	579.49	566.06	23.34	304.27
7	610.28	1.04	.57	10.40	1.36	1.30	1.30	580.79	567.36	7.25	311.52
8	700.02	1.03	.69	10.40	1.36	57.54	57.52	638.33	624.88	37.15	348.67
9	835.57	1.03	.66	10.40	1.36	78.98	78.96	717.31	703.84	77.55	426.22
10	1097.52	1.00	.79	10.40	1.36	165.66	165.49	882.97	869.33	97.42	523.64
11	1390.79	1.01	.79	10.40	1.36	175.15	175.02	1058.12	1044.35	95.76	619.40
12	1400.25	1.02	.79	10.40	1.36	10.14	10.14	1068.25	1054.50	16.92	636.32

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	7.50	1.00	.66	10.40	1.36	20.98	18.59	20.98	18.59	9.50	9.50
2	14.30	1.01	.66	10.40	1.36	13.00	12.93	33.98	31.51	8.28	17.78
3	39.26	1.03	.66	10.40	1.36	38.52	38.03	72.50	69.54	38.11	55.89
4	41.68	1.30	.66	10.40	1.36	4.20	4.20	76.70	73.73	8.40	64.29
5	58.89	1.09	.66	10.40	1.36	23.69	23.65	100.39	97.39	28.50	92.79
6	98.34	1.00	.66	10.40	1.36	44.47	44.31	144.86	141.70	38.20	130.99
7	165.30	1.00	.66	10.40	1.36	61.33	61.13	206.19	202.83	38.00	168.99
8	198.60	1.04	.66	10.40	1.36	36.05	36.03	242.24	238.86	22.70	191.69
9	248.23	1.05	.66	10.40	1.36	44.39	44.36	286.63	283.22	26.68	218.37
10	289.30	1.03	.66	10.40	1.36	34.27	34.26	320.89	317.48	38.60	256.97
11	336.44	1.03	.66	10.40	1.36	37.83	37.82	358.72	355.29	38.42	295.39
12	483.10	1.02	.88	10.40	1.36	144.87	144.62	503.60	499.91	79.95	375.34
13	673.94	1.01	1.04	10.40	1.36	201.14	200.84	704.73	700.75	72.42	447.76
14	839.97	1.03	.79	10.40	1.36	128.92	128.84	833.65	829.58	72.05	519.81
15	909.19	1.01	.79	10.40	1.36	49.95	49.94	883.60	879.52	44.55	564.36
16	1017.26	1.01	.59	10.40	1.36	55.29	55.28	938.89	934.80	61.77	626.13
17	1040.43	1.00	.68	10.40	1.36	16.08	16.08	954.97	950.88	17.50	643.63
18	1047.94	1.06	.68	10.40	1.36	1.57	1.57	956.54	952.46	6.50	650.13
19	1140.31	1.05	.68	10.40	1.36	65.04	65.03	1021.58	1017.49	63.03	713.16
20	1319.62	1.02	.59	10.40	1.36	85.84	85.81	1107.42	1103.30	84.90	798.06
21	1511.14	1.03	.69	10.40	1.36	109.53	109.50	1216.95	1212.80	89.40	887.46

Appendix A-3 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	62.89	1.01	.92	10.40	1.36	99.25	86.70	99.25	86.70	54.08	54.08
2	206.52	1.05	.93	10.40	1.36	123.72	121.74	222.97	209.45	73.67	127.75
3	237.44	1.03	.93	10.40	1.36	20.91	20.91	243.88	229.35	33.08	160.83
4	253.76	1.00	.91	10.40	1.36	14.09	14.08	257.97	243.44	16.50	177.33
5	456.60	1.02	.93	10.40	1.36	136.04	135.36	394.01	378.79	62.00	239.33
6	610.77	1.01	.92	10.40	1.36	89.87	89.76	483.88	468.55	48.67	288.00
7	876.31	1.01	.97	10.40	1.36	147.89	147.60	631.77	616.16	87.42	375.42
8	1055.24	1.04	.93	10.40	1.36	91.65	91.60	723.42	707.76	66.47	441.89
9	1367.17	1.02	.96	10.40	1.36	150.93	150.78	874.34	858.53	96.00	537.89
10	1649.07	1.03	.96	10.40	1.36	129.21	129.14	1003.56	987.68	87.58	625.47
11	1917.83	1.06	.93	10.40	1.36	118.79	118.74	1122.33	1106.41	62.25	687.72
12	2247.49	1.02	.93	10.40	1.36	131.12	131.07	1253.45	1237.48	65.84	753.56
13	2567.02	1.00	.96	10.40	1.36	127.40	127.36	1380.85	1364.85	70.58	824.14
14	2811.60	1.02	.82	10.40	1.36	81.30	81.29	1462.14	1446.13	75.84	899.98
15	2863.80	1.12	.87	10.40	1.36	18.98	18.98	1481.12	1465.11	42.25	942.23
16	2939.20	1.07	.79	10.40	1.36	24.27	24.27	1505.39	1489.38	31.25	973.48

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	17.31	1.02	.92	10.40	1.36	45.09	39.48	45.09	39.46	14.92	14.92
2	132.04	1.01	.86	10.40	1.36	107.94	104.02	153.04	143.51	75.91	90.63
3	139.31	1.07	.84	10.40	1.36	38.93	38.97	191.96	182.38	26.09	116.92
4	327.55	1.02	.73	10.40	1.36	137.31	135.91	329.27	318.29	85.50	202.42
5	522.16	1.03	.76	10.40	1.36	125.45	125.05	454.72	443.34	86.25	288.67
6	687.04	1.00	.78	10.40	1.36	95.76	95.65	550.48	539.00	55.42	344.09
7	997.97	1.01	.77	10.40	1.36	161.62	161.30	712.10	700.29	103.83	447.92
8	1281.46	1.00	.81	10.40	1.36	146.51	146.37	858.61	846.66	99.33	547.25
9	1581.61	1.00	.86	10.40	1.36	151.29	151.19	1009.90	997.86	97.75	645.00
10	1679.66	1.02	.90	10.40	1.36	51.14	51.14	1061.03	1048.99	64.82	709.62
11	1915.96	1.02	.79	10.40	1.36	105.08	105.06	1166.12	1154.05	89.83	799.65
12	2130.52	1.01	.83	10.40	1.36	99.58	99.57	1265.70	1253.61	96.92	896.57
13	2391.57	1.01	.82	10.40	1.36	107.44	107.42	1373.14	1361.03	82.49	979.06
14	2560.64	1.01	.78	10.40	1.36	66.98	66.98	1440.12	1428.01	80.58	1059.64
15	2595.78	1.01	.76	10.40	1.36	13.63	13.63	1453.74	1441.63	38.16	1097.80
16	2845.01	1.01	.76	10.40	1.36	94.06	94.05	1547.81	1535.68	119.07	1216.87
17	2934.87	1.00	.72	10.40	1.36	31.20	31.20	1579.01	1566.89	51.17	1268.04

Appendix A-3 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B NORTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	18.00	1.00	.90	12.19	.68	32.94	30.42	32.94	30.42	39.00	39.00
2	39.00	1.06	.90	12.19	.68	30.20	30.04	63.14	60.45	38.90	77.90
3	140.00	1.00	.90	12.19	.68	111.96	110.44	175.10	170.89	74.30	152.20
4	282.00	1.09	.93	12.19	.68	146.89	146.24	321.99	317.13	79.40	231.60
5	366.00	1.06	.85	12.19	.68	70.97	70.92	392.96	388.05	74.80	306.40
6	418.00	1.00	.77	12.19	.68	36.56	36.55	429.52	424.61	41.30	347.70
7	500.00	1.01	.80	12.19	.68	58.84	58.83	488.36	483.43	77.80	425.50
8	605.00	1.03	.84	12.19	.68	77.01	76.98	565.37	560.42	95.80	521.30
9	636.00	1.04	.76	12.19	.68	20.41	20.41	585.79	580.83	44.70	566.00
10	709.00	1.00	.81	12.19	.68	48.46	48.45	634.25	629.28	62.60	628.60
11	737.00	1.03	.96	12.19	.68	19.13	19.13	653.38	648.41	41.80	670.40
12	830.00	1.05	.85	12.19	.68	47.68	47.68	701.06	696.09	48.30	718.70
13	874.00	1.04	.85	12.19	.68	51.14	51.14	752.20	747.23	49.10	767.80
14	950.00	1.11	.85	12.19	.68	55.68	55.68	807.88	802.91	45.40	813.20
15	975.00	1.00	.88	12.19	.68	16.92	16.92	824.80	819.83	19.00	832.20

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B NORTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	32.00	1.00	.90	12.19	.68	56.76	51.18	56.76	51.18	55.00	55.00
2	175.00	1.00	.89	12.19	.68	149.66	145.56	206.42	196.74	65.60	120.60
3	284.00	1.00	.90	12.19	.75	103.57	103.29	309.99	300.03	77.20	197.80
4	357.00	1.02	1.02	12.19	.75	69.13	69.09	379.12	369.13	49.10	246.90
5	439.00	1.04	.87	12.19	.75	68.06	68.02	447.18	437.15	58.50	305.40
6	466.00	1.01	.87	12.19	.75	25.04	25.04	472.22	462.18	64.80	370.20
7	521.00	1.06	.80	12.19	.75	40.98	40.97	513.19	503.15	61.50	431.70
8	602.00	1.01	.84	12.19	.75	58.54	58.53	571.73	561.68	82.20	513.90
9	739.00	1.01	.86	12.19	.75	96.34	96.29	668.07	657.97	92.20	606.10
10	850.00	1.02	.96	12.19	.75	78.29	78.27	746.36	736.24	60.70	666.80
11	948.00	1.02	.81	12.19	.75	61.84	61.83	808.20	798.07	58.10	724.90
12	975.00	1.12	.87	12.19	.75	19.66	19.66	827.86	817.73	24.50	749.40

Appendix A-3 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B SOUTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	7.50	1.12	1.19	12.19	.68	23.70	21.99	23.70	21.99	6.60	6.60
2	26.50	1.05	1.13	12.19	.68	37.98	37.51	61.69	59.50	25.20	31.80
3	47.50	1.04	1.07	12.19	.68	26.27	26.22	87.96	65.72	18.50	50.30
4	79.00	1.00	.98	12.19	.68	47.92	47.76	135.88	133.48	31.00	81.30
5	135.00	1.10	.91	12.19	.68	66.94	66.77	202.81	200.24	51.50	132.80
6	195.00	1.10	.91	12.19	.68	66.26	66.18	269.07	266.42	57.40	190.20
7	277.00	1.05	.82	12.19	.68	73.58	73.50	342.65	339.92	61.40	251.60
8	353.00	1.13	.86	12.19	.68	72.25	72.21	414.90	412.13	78.60	330.20
9	419.00	1.01	.90	12.19	.66	56.45	56.44	471.35	468.57	59.70	389.90
10	430.50	1.16	.90	12.19	.68	11.13	11.13	482.49	479.70	10.00	399.90
11	449.00	1.18	.94	12.19	.68	18.89	16.89	501.38	498.59	25.70	425.60
12	510.00	1.07	.96	12.19	.68	51.51	51.50	552.89	550.10	62.10	487.70
13	570.00	1.06	.75	12.19	.68	48.44	48.43	601.33	598.53	68.70	556.40
14	596.00	1.18	.77	12.19	.68	13.60	13.60	614.93	612.13	16.10	572.50
15	631.50	1.11	.86	12.19	.68	29.45	29.48	644.41	641.61	53.70	626.20
16	704.00	1.13	.90	12.19	.68	63.22	63.21	707.63	704.83	65.50	691.70
17	834.50	1.01	.90	12.19	.68	76.73	76.72	784.36	781.54	77.70	769.40
18	955.00	1.14	.90	12.19	.68	45.34	45.33	829.69	826.88	52.00	821.40
19	959.50	1.06	.79	12.19	.66	70.59	70.58	900.29	897.46	68.50	889.90
20	1085.00	1.01	.81	12.19	.68	81.71	81.70	982.00	979.16	126.80	1016.70

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B SOUTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
21	1209.00	1.07	.81	12.19	.68	83.85	83.84	1065.84	1063.00	86.30	1103.00
22	1306.00	1.04	.84	12.19	.68	64.79	64.78	1130.63	1127.78	66.50	1169.50
23	1454.00	1.08	.87	12.19	.68	69.28	69.28	1199.91	1197.06	68.70	1238.20
24	1529.50	1.03	.87	12.19	.68	83.70	83.70	1283.62	1280.76	63.40	1321.60
25	1655.00	1.02	.85	12.19	.68	82.01	82.00	1365.62	1362.76	84.70	1406.30

ppendix A-3 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1a SOUTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	72.00	1.00	.81	12.19	.68	93.73	86.90	93.73	86.90	64.00	64.00
2	139.00	1.10	.77	12.19	.68	69.37	69.11	163.11	156.01	73.90	137.90
3	257.00	1.00	.76	12.19	.68	93.58	93.29	256.69	249.30	82.00	219.90
4	398.00	1.01	.81	12.19	.68	118.91	118.68	375.59	367.98	76.10	296.00
5	569.00	1.00	.82	12.19	.68	129.02	128.88	504.62	496.86	85.60	381.60
6	661.00	1.01	.76	12.19	.66	63.11	63.10	567.73	559.96	54.40	436.00
7	802.00	1.01	.80	12.19	.66	97.54	97.50	665.26	657.46	83.00	519.00
8	964.00	1.01	.80	12.19	.68	108.43	108.39	773.69	765.85	89.20	608.20
9	1114.00	1.00	.79	12.19	.68	95.60	95.58	869.29	861.44	97.00	705.20
10	1247.00	1.00	.81	12.19	.68	84.71	84.70	954.01	946.14	91.00	796.20
11	1376.00	1.01	.81	12.19	.68	81.19	81.18	1035.20	1027.32	80.30	876.50
12	1485.00	1.09	.87	12.19	.68	77.98	77.98	1113.18	1105.30	73.40	949.90
13	1587.00	1.04	.84	12.19	.66	63.13	63.12	1176.31	1168.43	70.30	1020.20
14	1654.00	1.02	.84	12.19	.68	45.61	45.61	1221.92	1214.04	62.30	1082.50

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 100091
D-9 SOUTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	DOWN HOURS CORRECTION	SOIL CORRECTION	SHIELD CORRECTION	EXCAVATING EQUIPMENT CORRECTION	WEEK'S HOURS INTEGRATION	WEEK'S HOURS SUMMATION	CUMULATIVE HOURS INTEGRATION	CUMULATIVE HOURS SUMMATION	ACTUAL HOURS WEEKS	ACTUAL HOURS CUMULATIVE
1	29.00	1.02	.75	11.40	.82	72.81	65.88	72.81	65.88	94.75	94.75
2	112.90	1.04	.75	11.40	.82	143.36	140.61	216.17	206.49	105.00	199.75
3	217.90	1.04	.82	11.40	.82	157.47	156.71	373.65	363.20	111.33	311.08
4	307.90	1.09	.79	11.40	.82	112.70	112.57	486.35	475.77	106.00	417.08
5	378.90	1.07	.74	11.40	.82	91.17	91.11	577.51	566.88	93.00	510.08
6	501.90	1.07	.75	11.40	.82	137.93	137.90	715.44	704.68	110.00	620.08
7	637.90	1.08	.75	11.40	.82	114.77	114.72	830.21	819.41	110.00	730.08
8	699.90	1.00	.75	11.40	.82	88.42	88.40	918.63	907.81	107.00	837.08
9	728.90	1.12	.75	11.40	.82	26.40	26.40	945.04	934.21	30.00	867.08

Appendix A-3 (continued)

Appendix A-4

Total downtime hours for each data set of each tunnel are calculated from equation (6.4).

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	15.00	2.21	22.18	3.31	3.31	.00	.00
2	47.50	2.21	22.15	7.16	10.46	7.50	7.50
3	235.00	2.21	21.96	40.97	51.43	10.50	18.00
4	332.50	2.21	21.65	20.99	72.42	79.00	97.00
5	552.50	2.42	21.17	50.70	123.12	9.00	106.00
6	680.00	2.42	20.54	28.50	151.62	22.00	128.00
7	825.00	2.85	19.97	37.20	188.82	66.50	194.50
8	1085.00	2.85	19.04	63.62	252.44	26.00	220.50
9	1277.50	2.61	17.68	60.85	313.29	26.50	247.00
10	1502.50	2.61	16.62	24.45	337.73	36.00	283.00
11	1657.50	2.61	15.91	29.02	366.75	43.00	326.00
12	1950.00	2.61	15.05	34.08	400.84	30.00	356.00
13	1960.00	3.21	14.32	22.80	423.64	69.50	425.50
14	2050.00	3.21	13.85	18.05	441.68	8.00	433.50
15	2300.00	3.21	13.09	47.38	489.06	33.50	467.00
16	2557.50	3.21	12.04	44.89	533.95	38.00	505.00
17	2857.50	3.21	11.02	47.88	581.84	25.00	530.00
18	3102.50	2.84	10.18	31.92	613.76	20.00	550.00
19	3340.00	2.84	9.55	29.03	642.79	31.50	581.50
20	3597.50	7.47	9.03	78.17	720.95	26.50	608.00

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
21	3955.00	2.84	8.61	28.40	749.35	25.50	633.50
22	4102.50	2.84	8.34	26.43	775.78	28.50	662.00
23	4297.50	2.84	8.22	20.52	796.30	37.00	699.00
24	4345.00	2.84	8.20	4.98	801.28	79.00	778.00
25	4425.00	3.85	8.20	11.38	812.66	16.50	794.50

Appendix A-4. Calculation of Downtime Hours.

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	20.00	2.21	22.18	4.41	4.41	6.50	6.50
2	52.50	2.21	22.15	7.16	11.57	6.50	13.00
3	175.00	2.21	22.03	26.83	38.39	44.50	57.50
4	735.00	2.21	21.72	34.56	72.95	31.00	88.50
5	555.00	2.42	21.16	50.68	123.63	7.00	95.50
6	792.50	2.85	20.30	61.96	185.56	18.50	114.00
7	1162.50	2.85	18.94	90.02	275.60	8.00	122.00
8	1350.00	2.61	17.55	38.73	314.33	17.50	139.50
9	1487.50	2.61	16.73	27.06	341.40	15.00	154.50
10	1515.50	2.61	16.31	5.28	346.67	110.00	264.50
11	1695.00	2.61	15.78	33.43	380.11	35.50	300.00
12	1970.00	2.61	14.91	30.69	410.80	27.00	327.00
13	1935.00	3.21	14.33	13.48	424.29	61.00	388.00
14	1967.50	3.21	13.98	4.55	428.84	92.50	480.50
15	2162.50	3.21	13.53	34.29	463.12	54.00	534.50
16	2495.00	3.21	12.44	59.89	523.02	16.50	551.00
17	2577.50	3.21	11.63	13.89	536.91	63.50	614.50
18	2787.50	3.21	11.11	33.78	570.69	19.00	633.50
19	3080.00	2.84	10.31	38.61	609.29	26.50	660.00
20	3265.00	2.84	9.64	25.30	634.60	24.50	684.50

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1M0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
21	3510.00	2.61	9.17	24.81	659.41	27.50	712.00
22	3795.00	7.47	8.72	83.56	742.97	25.00	737.00
23	4120.00	2.64	8.36	34.79	777.76	16.00	753.00
24	4280.00	2.84	8.22	16.83	794.59	12.50	765.50
25	4790.00	3.85	8.20	15.64	810.23	11.00	776.50

Appendix A-4 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
RR/RL TUNNELS
BERKELEY, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	28.00	2.38	2.44	.52	.52	12.00	12.00
2	90.00	2.38	2.44	1.62	2.14	.00	12.00
3	163.00	2.38	2.42	1.90	4.04	2.00	14.00
4	212.00	2.38	2.41	1.27	5.31	9.00	23.00
5	264.00	2.38	2.40	1.34	6.65	6.00	29.00
6	320.00	2.38	2.38	1.43	8.08	1.00	30.00
7	367.00	2.38	2.37	1.19	9.27	40.00	70.00
8	443.00	2.38	2.34	1.91	11.18	2.00	72.00
9	529.00	2.38	2.31	2.14	13.32	.00	72.00
10	616.00	2.38	2.28	2.13	15.45	2.00	74.00
11	712.00	2.38	2.24	2.31	17.75	9.00	83.00
12	771.00	2.38	2.20	1.40	19.15	2.00	85.00
13	862.00	2.38	2.17	2.12	21.27	3.00	88.00
14	944.00	2.38	2.12	1.87	23.14	7.00	95.00
15	1016.00	1.31	2.08	.88	24.02	21.00	116.00
16	1099.00	1.31	2.04	1.00	25.02	1.00	117.00
17	1157.00	1.31	2.00	.68	25.70	2.00	119.00
18	1225.00	1.31	1.97	.80	26.50	.00	119.00
19	1290.00	1.52	1.93	.86	27.36	.00	119.00
20	1374.00	1.52	1.89	1.09	28.45	1.00	120.00

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
RR/RL TUNNELS
BERKELEY, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
21	1459.00	1.52	1.84	1.07	29.52	1.00	121.00
22	1474.00	1.52	1.81	.19	29.71	.00	121.00
23	1479.00	1.52	1.81	.06	29.77	.00	121.00
24	1598.00	5.20	1.77	4.94	34.71	5.00	126.00
25	1672.00	5.20	1.72	2.98	37.69	2.00	128.00
26	1810.00	5.20	1.66	5.37	43.06	1.00	129.00
27	1943.00	5.20	1.59	4.95	48.02	8.00	137.00
28	2059.00	5.20	1.53	4.15	52.16	17.00	154.00
29	2199.00	5.20	1.46	4.80	56.96	2.00	156.00
30	2329.00	5.20	1.40	4.26	61.22	8.00	164.00
31	2368.00	5.20	1.36	1.24	62.46	51.00	215.00
32	2462.00	1.52	1.33	.86	63.32	3.00	218.00
33	2546.00	1.52	1.29	.74	64.06	4.00	222.00
34	2650.00	1.52	1.26	.89	64.96	1.00	223.00
35	2746.00	1.52	1.22	.80	65.76	.00	223.00
36	2910.00	1.52	1.19	.52	66.28	43.00	266.00
37	2988.00	1.52	1.16	.62	66.90	2.00	268.00
38	2903.00	1.52	1.15	.12	67.01	.00	268.00

Appendix A-4 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TR TUNNEL
SAN FRANCISCO, CALIFORNIA

			EQUIPMENT/	CALCULATED		ACTUAL	
	CUMULATIVE	SOIL	DISTANCE	DOWN HOURS		DOWN HOURS	
WEEK	FEET	CORRECTION	CORRECTION	WEEK'S	CUMULATIVE	WEEK'S	CUMULATIVE
1	47.43	4.17	89.04	16.96	16.96	1.00	1.00
2	194.73	2.21	89.44	27.67	44.63	3.58	4.58
3	362.07	2.21	30.10	10.70	55.33	3.40	7.96
4	566.85	2.51	29.32	14.48	69.82	3.74	11.72
5	696.74	7.89	18.99	18.74	88.56	18.55	30.27
6	968.96	4.74	27.50	24.12	112.68	16.43	46.70
7	1116.23	2.21	26.14	12.62	125.30	12.92	59.62
8	1353.38	2.21	24.54	12.36	137.66	10.19	69.81
9	1463.21	4.45	23.32	10.96	148.62	.00	69.81
10	1515.49	7.89	15.18	6.03	154.65	15.25	85.06
11	1550.48	7.89	14.98	3.98	158.63	1.17	86.23

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TL TUNNEL
SAN FRANCISCO, CALIFORNIA

			EQUIPMENT/	CALCULATED		ACTUAL	
	CUMULATIVE	SOIL	DISTANCE	DOWN HOURS		DOWN HOURS	
WEEK	FEET	CORRECTION	CORRECTION	WEEK'S	CUMULATIVE	WEEK'S	CUMULATIVE
1	44.76	7.89	12.80	20.37	20.37	4.40	4.40
2	137.34	3.67	12.75	19.53	39.90	6.83	11.23
3	309.61	2.21	12.59	21.56	61.47	1.91	13.14
4	469.43	2.21	6.33	10.06	71.53	1.00	14.14
5	629.31	2.51	6.17	11.14	82.67	1.75	15.89
6	826.69	2.51	5.96	13.28	95.95	6.88	22.77
7	1054.04	2.21	5.67	12.82	108.76	14.91	37.68
8	1[illegible]1.41	2.85	5.34	15.58	124.34	13.40	51.08
9	1451.36	3.67	4.69	13.19	137.53	26.06	77.14
10	1516.29	7.89	7.29	16.83	154.35	1.00	78.14
11	1551.29	7.89	7.18	6.93	163.28	2.92	81.06

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
SR TUNNEL
SAN FRANCISCO, CALIFORNIA

			EQUIPMENT/	CALCULATED		ACTUAL	
	CUMULATIVE	SOIL	DISTANCE	DOWN HOURS		DOWN HOURS	
WEEK	FEET	CORRECTION	CORRECTION	WEEK'S	CUMULATIVE	WEEK'S	CUMULATIVE
1	42.50	2.21	19.03	8.04	8.04	21.83	21.83
2	165.10	3.23	18.92	33.80	41.84	3.17	25.00
3	212.63	2.21	18.78	8.87	50.71	1.59	26.59
4	325.03	3.23	6.44	10.55	61.26	10.17	36.76
5	489.91	3.23	6.32	15.18	76.44	5.67	42.43
6	654.75	5.38	6.15	24.58	101.02	9.27	51.70
7	839.32	4.17	5.94	20.60	121.62	14.00	65.70
8	1031.61	2.21	5.68	10.86	132.48	28.69	94.39
9	1236.34	2.26	5.39	11.26	143.74	.42	94.81
10	1415.75	2.21	5.11	9.11	152.85	.00	94.81
11	1552.94	2.21	4.24	5.79	158.63	12.50	107.31

Appendix A-4 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 150011
5L TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	29.93	2.21	114.82	2.02	2.02	.00	.00
2	109.53	7.89	114.43	19.13	21.15	.50	.50
3	209.45	7.89	113.60	23.83	44.98	6.75	7.25
4	326.95	7.89	112.31	27.70	72.68	3.50	10.75
5	386.93	7.89	111.03	13.98	86.66	8.00	18.75
6	525.83	7.89	109.39	31.89	118.55	8.75	27.50
7	639.23	2.21	107.01	7.12	125.67	9.41	36.91
8	796.72	2.21	104.16	9.63	135.30	5.75	42.66
9	851.61	2.21	101.75	3.28	138.58	4.00	46.66
10	981.25	2.21	99.54	7.57	146.15	25.42	72.08
11	1116.09	7.89	96.25	27.24	173.40	22.08	94.16
12	1295.74	2.21	92.20	9.72	183.12	6.41	100.57
13	1457.86	2.21	131.41	12.50	195.62	28.89	129.46
14	1565.19	2.21	94.17	5.30	200.93	5.33	134.79

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 15D051A
5L TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	85.00	2.85	130.53	5.18	5.18	3.67	3.67
2	152.50	3.23	129.95	7.55	12.73	17.78	21.45
3	220.00	2.51	129.16	5.81	18.54	17.14	38.59
4	280.00	2.21	128.29	4.52	23.06	3.58	42.17
5	350.00	2.21	127.28	5.23	28.29	2.08	44.25
6	457.20	2.51	125.71	8.98	37.27	10.17	54.42
7	564.70	2.21	123.56	7.80	45.07	6.32	60.74
8	689.70	2.21	120.95	8.87	53.94	11.68	72.42
9	729.70	2.21	118.94	2.79	56.74	7.01	79.43

BAY AREA RAPID TRANSIT
CONTRACT NUMBER 15D051A
SR TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	27.46	3.67	319.73	7.03	7.03	.00	.00
2	94.96	4.17	318.85	23.89	30.92	7.50	7.50
3	137.46	6.12	317.56	21.96	52.88	10.33	17.83
4	190.24	2.21	73.02	2.26	55.14	2.33	20.16
5	277.46	5.38	72.50	9.06	64.20	9.15	29.31
6	384.96	4.17	71.64	8.55	72.75	17.28	46.59
7	477.46	2.21	70.62	3.83	76.58	5.42	52.01
8	564.96	2.21	69.58	3.57	80.15	7.34	59.35
9	687.46	3.23	68.24	7.19	87.34	9.17	68.52
10	709.96	3.23	67.25	1.30	88.65	11.75	80.27

Appendix A-4 (continued)

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	24.00	10.46	4.26	4.81	4.81	8.00	8.00
2	38.00	9.46	4.25	2.54	7.35	28.00	36.00
3	130.00	9.46	4.24	16.62	23.97	6.00	42.00
4	210.00	3.58	4.21	5.44	29.41	24.00	66.00
5	214.00	3.58	4.19	.27	29.68	5.00	71.00
6	242.00	12.82	4.18	6.76	36.44	36.00	107.00
7	265.00	2.65	4.17	1.14	37.58	12.00	119.00
8	284.00	2.65	4.16	.94	38.53	8.00	127.00
9	358.00	2.99	4.14	4.12	42.65	20.00	147.00
10	410.00	3.58	4.10	3.44	46.09	21.00	168.00
11	590.00	3.58	4.03	11.70	57.79	8.00	176.00
12	706.00	3.59	3.92	7.34	65.13	23.00	199.00
13	838.00	3.58	3.82	8.14	73.27	18.00	217.00
14	1094.00	3.63	3.65	15.25	88.52	12.00	229.00
15	1262.00	2.63	3.40	10.66	99.18	12.00	241.00
16	1466.00	3.38	3.22	5.10	104.28	27.50	268.50
17	1510.00	29.37	3.14	18.31	122.58	29.50	298.00
18	1530.00	21.68	3.11	6.08	128.66	4.00	302.00
19	1586.00	9.78	3.08	7.59	136.26	6.50	310.50
20	1668.00	12.47	3.01	13.87	150.13	13.00	323.50

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
21	1822.00	5.11	2.90	10.28	160.40	11.50	335.00
22	2002.00	3.17	2.74	7.06	167.46	13.00	348.00
23	2075.00	12.75	2.63	11.03	178.49	14.00	362.00
24	2139.00	10.26	2.53	19.17	197.66	7.00	369.00
25	2274.00	10.26	2.45	3.96	201.62	25.00	394.00
26	2338.00	9.46	2.41	6.56	208.18	21.00	415.00
27	2517.00	9.46	2.31	17.26	225.44	16.00	431.00
28	2833.00	7.67	2.14	24.28	249.72	5.00	436.00
29	3041.00	3.58	1.98	6.64	256.36	11.00	447.00
30	3349.00	2.63	1.85	6.74	263.10	11.00	458.00
31	3625.00	12.59	1.73	27.02	290.12	13.00	471.00
32	3953.00	2.55	1.65	4.32	294.44	19.00	490.00
33	4229.00	2.64	1.59	7.12	301.56	.00	490.00
34	4445.00	4.98	1.57	7.62	309.18	16.00	506.00
35	4725.00	10.15	1.59	20.35	329.53	6.00	512.00
36	4977.00	9.41	1.63	10.49	340.02	14.50	526.50
37	5177.00	2.65	1.70	6.08	346.11	11.00	537.50
38	5461.00	2.65	1.86	6.74	352.85	13.00	550.50
39	5881.00	2.65	2.17	10.34	363.18	5.00	555.50
40	6167.00	9.46	2.66	32.45	395.64	16.50	572.00

Appendix A-4 (continued)

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-2S
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
41	6345.00	9.21	3.17	23.37	419.01	19.00	591.00
42	6445.00	9.21	3.56	14.77	433.77	20.00	611.00
43	6493.00	9.21	3.81	7.58	441.35	23.00	634.00
44	6519.00	9.78	3.94	4.52	445.87	27.00	661.00
45	6565.00	9.21	4.08	7.78	453.65	20.00	681.00
46	6663.00	9.21	4.38	17.81	471.46	15.00	696.00
47	6825.00	9.21	5.02	33.75	505.21	12.00	708.00
48	7073.00	2.57	6.36	18.30	523.51	6.00	714.00

UPPER SALT CREEK #2
CONTRACT NUMBER 68-405-2S
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	46.00	2.65	.31	.17	.17	.00	.00
2	69.00	2.65	.31	.08	.25	.00	.00
3	172.00	2.65	.31	.38	.63	16.00	16.00
4	365.00	2.65	4.40	11.16	11.79	5.00	21.00
5	963.00	2.81	4.12	30.16	41.96	8.00	29.00
6	1122.00	2.65	3.78	7.16	49.12	26.00	55.00
7	1671.00	16.14	3.42	136.42	185.54	26.00	81.00
8	1989.00	4.66	3.03	13.86	199.40	28.00	109.00
9	2384.00	2.73	2.69	16.36	215.76	17.00	126.00
10	3006.00	2.55	2.25	16.04	231.80	9.00	135.00
11	3110.00	1.57	2.02	1.49	233.29	13.00	148.00
12	3680.00	1.57	1.86	7.52	240.81	5.00	153.00
13	4091.00	2.90	1.71	9.18	249.99	17.00	170.00
14	4604.00	2.65	1.66	10.17	260.16	8.00	178.00
15	4972.00	11.70	1.72	33.34	293.50	15.00	193.00
16	5313.00	9.46	1.95	26.93	320.42	10.00	203.00

Appendix A-4 (continued)

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	20.00	2.65	.38	.09	.09	30.00	30.00
2	104.00	3.58	5.52	7.49	7.58	12.00	42.00
3	268.00	11.01	3.21	26.08	33.66	10.00	52.00
4	388.00	3.58	5.38	10.42	44.08	17.00	69.00
5	526.00	3.58	5.28	11.76	55.84	9.00	78.00
6	678.00	2.99	5.14	10.52	66.36	1.00	79.00
7	942.00	10.05	4.98	36.99	103.34	9.00	88.00
8	1110.00	3.27	4.73	18.69	122.04	4.00	92.00
9	1230.00	10.58	4.49	25.69	147.73	26.00	118.00
10	1337.00	9.33	3.34	15.05	162.77	27.00	145.00
11	1417.00	2.64	3.25	3.09	165.87	23.00	168.00
12	1581.00	2.65	3.13	6.12	171.99	9.50	177.50
13	1781.00	2.65	2.96	7.05	179.04	8.00	185.50
14	1993.00	2.65	2.81	3.75	182.79	12.00	197.50
15	2153.00	2.65	2.64	8.19	190.99	3.00	200.50
16	2477.00	2.65	2.40	9.27	200.25	.00	200.50
17	2729.00	2.65	2.19	6.57	206.82	13.00	213.50
18	3029.00	4.03	2.01	10.95	217.77	5.50	219.00
19	3309.00	3.18	1.86	7.45	225.22	9.00	228.00
20	3685.00	2.65	1.72	7.72	232.94	2.00	230.00

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
21	3897.00	2.65	1.64	4.19	237.08	16.00	246.00
22	4297.00	2.65	1.59	7.56	244.64	3.00	249.00
23	4565.00	2.65	1.58	5.41	250.05	1.50	250.50
24	4726.00	2.65	1.60	2.69	252.74	16.00	266.50
25	4806.00	2.42	1.62	1.41	254.15	25.00	291.50
26	4974.00	3.24	1.65	4.05	258.20	8.00	299.50
27	5066.00	2.65	1.74	6.06	264.27	3.00	302.50
28	5582.00	2.65	1.93	7.26	271.53	3.50	306.00
29	5838.00	3.31	2.20	8.42	279.95	9.00	315.00

Appendix A-4 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	67.00	5.20	1.65	2.59	2.59	10.01	10.01
2	113.19	5.20	1.65	1.78	4.37	6.72	16.73
3	288.08	7.89	1.63	10.13	14.50	8.82	25.55
4	339.50	12.47	1.61	4.65	19.14	5.35	30.90
5	553.44	8.21	1.56	12.49	31.63	3.67	34.57
6	607.81	8.21	1.54	3.10	34.73	3.16	37.73
7	610.28	5.20	1.53	.09	34.82	.25	37.98
8	702.02	16.14	1.52	10.13	44.95	11.35	49.33
9	935.57	8.21	1.48	7.33	52.28	16.95	66.28
10	1097.52	8.21	1.42	13.72	66.01	10.58	76.86
11	1390.79	6.21	1.31	14.25	80.26	14.74	91.60
12	1408.25	8.21	1.25	.81	81.07	.58	92.18

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	7.50	5.20	1.65	.29	.29	.00	.00
2	14.30	5.20	1.65	.26	.55	.00	.00
3	39.26	5.20	1.65	.96	1.52	.89	.89
4	41.68	5.20	1.65	.09	1.61	1.60	2.49
5	58.99	5.20	1.65	.66	2.27	3.00	5.49
6	98.34	5.20	1.65	1.52	3.79	2.80	8.29
7	160.30	5.20	1.64	2.38	6.17	4.50	12.79
8	198.60	5.20	1.63	1.46	7.63	2.80	15.59
9	248.23	5.20	1.63	1.89	9.52	6.82	22.41
10	289.30	5.20	1.62	1.55	11.07	2.40	24.81
11	336.44	5.20	1.61	1.77	12.85	6.58	31.39
12	483.10	7.89	1.59	8.27	21.12	21.05	52.44
13	672.94	16.09	1.54	23.85	44.97	4.08	56.52
14	839.97	24.50	1.49	27.43	72.40	16.95	73.47
15	909.19	24.50	1.45	11.06	83.47	4.95	78.42
16	1013.26	16.14	1.42	10.72	94.19	9.73	88.15
17	1040.43	8.21	1.39	1.40	95.59	1.00	89.15
18	1042.94	8.21	1.39	.13	95.72	2.50	91.65
19	1149.31	6.21	1.37	5.39	101.11	32.47	124.12
20	1319.62	16.14	1.32	16.30	117.41	9.60	133.72
21	1511.14	16.14	1.25	17.38	134.79	11.10	144.82

Appendix A-4 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	69.89	6.64	1.65	3.45	3.45	2.42	2.42
2	206.52	7.14	1.64	7.20	10.65	18.83	21.25
3	233.84	7.84	1.63	1.57	12.22	1.42	22.67
4	253.76	7.30	1.62	1.06	13.28	.00	22.67
5	456.60	8.14	1.60	11.89	25.18	12.00	34.67
6	610.77	6.82	1.55	7.36	32.54	5.83	40.50
7	976.31	7.44	1.49	13.28	45.82	6.58	47.08
8	1055.24	7.84	1.42	8.95	54.77	24.03	71.11
9	1367.17	7.96	1.33	14.84	69.61	12.50	83.61
10	1648.07	7.67	1.21	11.78	81.39	20.92	104.53
11	1917.83	6.14	1.11	10.99	92.38	40.25	144.78
12	2242.49	7.84	1.01	11.55	103.93	17.66	162.44
13	2567.02	7.67	.90	10.15	114.08	2.92	165.36
14	2811.60	4.99	.83	4.54	118.62	16.66	182.02
15	2863.80	4.07	.79	.76	119.37	11.25	193.27
16	2938.20	3.00	.76	.78	120.15	13.75	207.02

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	17.31	24.50	1.65	3.16	3.16	2.58	2.58
2	102.04	12.72	1.65	8.01	11.17	10.59	13.17
3	139.31	7.12	1.64	1.96	13.13	8.91	22.08
4	327.55	8.81	1.62	12.13	25.26	13.00	35.08
5	522.16	5.13	1.58	7.12	32.39	12.25	47.33
6	687.04	5.18	1.53	5.90	38.29	8.08	55.41
7	993.97	6.05	1.46	12.21	50.49	7.67	63.08
8	1281.46	8.69	1.35	15.23	65.72	9.17	72.25
9	1581.61	13.16	1.24	22.10	87.82	10.75	83.00
10	1679.66	9.90	1.17	5.10	92.92	8.18	91.18
11	1915.98	9.53	1.11	11.22	104.14	10.67	101.85
12	2139.52	10.13	1.02	10.45	114.59	11.58	113.43
13	2391.57	9.67	.95	10.40	124.99	7.51	120.94
14	2560.64	14.84	.88	9.99	134.98	12.42	133.36
15	2595.38	10.02	.86	1.34	136.33	4.34	137.70
16	2845.01	9.79	.82	9.01	145.34	13.93	151.63
17	2934.87	4.46	.78	1.40	146.74	1.83	153.46

Appendix A-4 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F19 NORTH OUTBOUND
WASHINGTON, D.C.

			EQUIPMENT/	CALCULATED		ACTUAL	
	CUMULATIVE	SOIL	DISTANCE	DOWN HOURS		DOWN HOURS	
WEEK	FEET	CORRECTION	CORRECTION	WEEK'S	CUMULATIVE	WEEK'S	CUMULATIVE
1	18.00	4.86	4.33	1.71	1.71	.00	.00
2	39.00	4.86	4.33	1.99	3.70	6.10	6.10
3	140.00	4.86	4.31	9.53	13.23	1.70	7.80
4	262.00	5.83	4.26	15.89	29.12	16.60	24.40
5	366.00	5.34	4.21	8.50	37.62	17.70	42.10
6	418.00	3.12	4.17	3.05	40.67	2.20	44.30
7	500.00	3.39	4.13	5.17	45.84	8.20	52.50
8	605.00	3.85	4.06	7.38	53.23	7.70	60.20
9	636.00	3.43	4.01	1.92	55.15	12.30	72.50
10	709.00	3.79	3.97	4.94	60.09	3.90	76.40
11	733.00	5.59	3.93	2.37	62.46	8.20	84.60
12	900.00	4.29	3.89	5.03	67.49	8.70	93.30
13	974.00	4.29	3.83	5.47	72.97	7.90	101.20
14	950.00	4.78	3.76	6.16	79.13	11.60	112.80
15	975.00	4.86	3.71	2.03	81.16	.00	112.80

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F19 NORTH INBOUND
WASHINGTON, D.C.

			EQUIPMENT/	CALCULATED		ACTUAL	
	CUMULATIVE	SOIL	DISTANCE	DOWN HOURS		DOWN HOURS	
WEEK	FEET	CORRECTION	CORRECTION	WEEK'S	CUMULATIVE	WEEK'S	CUMULATIVE
1	32.00	4.68	4.33	2.92	2.92	1.00	1.00
2	175.00	5.01	4.31	13.90	16.82	6.40	7.40
3	284.00	4.68	1.90	4.36	21.18	3.30	10.70
4	353.00	7.88	1.88	4.60	25.78	7.40	18.10
5	434.00	6.89	1.86	4.67	30.45	8.00	26.10
6	466.00	7.38	1.84	1.96	32.40	11.20	37.30
7	521.00	7.89	1.83	3.57	35.98	7.70	45.00
8	602.00	7.89	1.81	5.20	41.18	3.80	48.80
9	738.00	7.89	1.77	8.55	49.73	3.30	52.10
10	850.00	7.89	1.72	6.86	56.56	3.80	55.90
11	948.00	6.34	1.68	4.70	61.29	6.40	62.30
12	975.00	6.54	1.65	1.32	62.60	3.00	65.30

Appendix A-4 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B SOUTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	7.50	9.21	4.33	1.35	1.35	9.40	9.40
2	26.50	8.13	4.33	3.01	4.36	14.80	24.20
3	42.50	7.17	4.33	2.24	6.60	5.50	29.70
4	79.00	6.33	4.32	4.50	11.09	2.00	31.70
5	135.00	4.95	4.31	5.37	16.47	12.50	44.20
6	195.00	4.95	4.28	5.73	22.20	20.10	64.30
7	277.00	3.39	4.25	5.33	27.53	16.10	80.40
8	353.00	3.85	4.21	5.55	33.08	24.90	105.30
9	419.00	4.36	4.17	5.40	38.48	11.80	117.10
10	430.50	4.36	4.15	.94	39.41	6.00	123.10
11	449.00	4.93	4.14	1.70	41.11	5.30	128.40
12	510.00	4.13	4.11	4.67	45.78	7.40	135.80
13	579.00	3.65	4.07	4.61	50.39	8.80	144.60
14	596.00	3.85	4.03	1.19	51.58	7.40	152.00
15	631.50	3.85	4.01	2.47	54.05	8.80	160.80
16	704.00	4.01	3.97	5.20	59.25	20.00	180.80
17	804.50	4.01	3.90	7.08	66.33	9.80	190.60
18	858.00	3.69	3.83	3.41	69.73	18.00	208.60
19	959.50	3.43	3.76	5.90	75.64	19.00	227.60
20	1065.00	4.47	3.66	9.24	84.88	11.20	238.80

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B SOUTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
21	1209.00	4.47	3.54	8.83	93.71	16.20	255.00
22	1306.00	4.71	3.43	7.06	100.77	9.50	264.50
23	1404.00	4.61	3.33	6.78	107.55	17.30	281.80
24	1529.50	4.61	3.22	8.39	115.94	12.10	293.90
25	1659.00	4.88	3.09	8.81	124.75	10.80	304.70

Appendix A-4 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B SOUTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	72.00	4.37	4.33	6.14	6.14	7.50	7.50
2	139.00	4.44	4.31	5.77	11.91	24.10	31.60
3	252.00	3.65	4.27	7.93	19.84	5.50	37.10
4	396.00	3.79	4.21	10.48	30.32	9.90	47.00
5	568.00	3.39	4.11	10.68	41.01	1.90	48.90
6	661.00	3.67	4.01	6.17	47.16	2.10	51.00
7	802.00	3.87	3.92	9.53	56.71	5.00	56.00
8	964.00	4.08	3.79	11.29	67.99	4.30	60.30
9	1114.00	3.73	3.64	9.17	77.17	2.00	62.30
10	1247.00	4.47	3.50	9.38	86.55	1.00	63.30
11	1376.00	4.31	3.37	8.45	95.00	3.70	67.00
12	1465.00	4.61	3.26	7.37	102.37	14.10	81.10
13	1562.00	4.54	3.15	6.26	108.63	11.70	92.80
14	1654.00	4.54	3.07	4.52	113.15	4.20	97.00

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 10C091
C-9 SOUTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE FEET	SOIL CORRECTION	EQUIPMENT/ DISTANCE CORRECTION	CALCULATED DOWN HOURS WEEK'S	CALCULATED DOWN HOURS CUMULATIVE	ACTUAL DOWN HOURS WEEK'S	ACTUAL DOWN HOURS CUMULATIVE
1	28.00	2.65	8.00	2.67	2.67	1.25	1.25
2	112.90	2.65	7.97	8.07	10.74	12.00	13.25
3	217.90	2.88	7.91	10.76	21.50	8.17	21.42
4	300.90	2.76	7.84	8.08	29.58	24.00	45.42
5	378.90	2.65	7.76	7.21	36.79	14.00	59.42
6	501.90	2.65	7.64	11.20	47.99	25.00	84.42
7	607.90	2.65	7.50	9.47	57.46	20.00	104.42
8	695.90	2.65	7.36	8.06	65.53	8.00	112.42
9	724.90	2.65	7.27	2.16	67.69	8.00	120.42

Appendix A-4 (continued)

Appendix A-5

The calculated rate of advance data of Appendix A-3 is combined with the downtime estimates of Appendix A-4 to give an estimate of the total tunneling shift hours for each data set of each tunnel. The percent error of the tunnel's cumulative hours relative to the reported hours is shown.

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER IM0031
MR TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	33.46	29.53	8.00	-318.24	-269.10
2	83.72	78.99	47.50	-76.24	-66.30
3	270.50	261.10	168.00	-61.01	-55.42
4	353.22	343.70	288.00	-22.65	-19.34
5	522.56	512.58	409.00	-28.08	-25.63
6	614.53	604.51	486.00	-26.45	-24.38
7	721.48	711.42	606.50	-18.96	-17.30
8	903.30	893.10	726.50	-24.34	-22.93
9	1083.16	1072.86	847.00	-27.88	-26.67
10	1161.87	1151.56	967.00	-20.15	-19.09
11	1256.03	1247.71	1067.00	-15.73	-14.76
12	1365.13	1354.80	1207.00	-13.10	-12.25
13	1445.22	1434.86	1326.50	-8.95	-8.17
14	1497.56	1487.23	1446.50	-3.53	-2.82
15	1639.96	1629.61	1566.00	-4.72	-4.06
16	1780.78	1770.40	1686.00	-5.62	-5.01
17	1932.85	1922.46	1806.00	-7.02	-6.45
18	2046.12	2035.72	1926.00	-6.24	-5.70
19	2154.47	2144.06	2045.50	-5.33	-4.82
20	2326.96	2316.54	2166.00	-7.43	-6.95
21	2434.53	2424.11	2286.50	-6.47	-6.02
22	2537.60	2527.17	2407.00	-5.43	-4.99
23	2618.86	2608.43	2527.00	-3.64	-3.22
24	2652.88	2642.45	2647.00	-.22	.17
25	2687.54	2677.11	2719.50	1.18	1.56

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER IM0031
ML TUNNEL - 24TH TO RANDALL STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	43.66	38.86	38.50	-13.40	-.94
2	92.23	86.91	79.00	-16.75	-10.02
3	254.00	246.16	199.50	-27.32	-23.39
4	414.34	405.76	319.50	-29.69	-27.00
5	593.55	584.50	439.50	-35.05	-32.99
6	782.97	773.69	560.00	-39.82	-38.16
7	1053.38	1043.72	680.00	-54.91	-53.49
8	1176.98	1167.29	757.50	-55.38	-54.10
9	1263.36	1253.66	835.50	-51.21	-50.05
10	1281.48	1271.56	955.50	-34.12	-33.08
11	1393.77	1364.06	1075.00	-29.65	-28.75
12	1500.12	1490.39	1195.00	-25.53	-24.72
13	1558.45	1548.72	1315.00	-18.51	-17.77
14	1638.62	1585.61	1435.50	-14.15	-10.46
15	1759.11	1706.09	1555.50	-13.09	-9.68
16	1951.66	1898.81	1676.00	-16.46	-13.29
17	2014.36	1961.31	1795.50	-12.19	-9.23
18	2130.45	2077.36	1915.50	-11.22	-8.45
19	2274.07	2220.99	2036.00	-11.69	-9.09
20	2374.18	2321.10	2155.50	-10.15	-7.68
21	2480.67	2429.42	2275.00	-9.04	-6.79
22	2679.24	2627.97	2395.00	-11.87	-9.73
23	2821.44	2770.16	2515.00	-12.18	-10.15
24	2891.15	2839.97	2635.50	-9.70	-7.75
25	2942.57	2891.29	2747.50	-7.10	-5.23

Appendix A-5. Total Estimated Shift Hours and Percentage of Error.

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1R0053
RR/RL TUNNELS
BERKELEY, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	153.76	92.52	88.00	-74.72	-5.13
2	354.05	289.72	208.00	-70.21	-39.29
3	547.82	482.65	328.00	-67.02	-47.15
4	680.83	615.55	448.00	-51.97	-37.40
5	859.19	743.84	568.00	-42.46	-30.96
6	930.73	865.32	688.00	-35.28	-25.77
7	1065.33	999.89	808.00	-31.85	-23.75
8	1216.67	1151.16	928.00	-31.11	-24.05
9	1380.33	1314.76	1048.00	-31.71	-25.45
10	1541.25	1475.63	1168.00	-31.96	-26.34
11	1715.14	1649.47	1288.00	-33.16	-24.06
12	1618.12	1752.44	1368.00	-32.90	-28.10
13	1972.37	1906.67	1488.00	-32.55	-28.14
14	2111.20	2045.48	1608.00	-31.29	-27.21
15	2230.26	2164.54	1728.00	-29.07	-25.26
16	2349.27	2283.49	1848.00	-27.12	-23.57
17	2431.97	2366.23	1944.00	-25.10	-21.72
18	2526.04	2461.69	2040.00	-23.83	-20.67
19	2626.37	2562.00	2160.00	-21.59	-18.61
20	2754.80	2690.43	2280.00	-20.82	-18.00
21	2882.79	2914.42	2400.00	-20.12	-17.43
22	2905.08	2840.70	2520.00	-15.28	-12.73
23	2912.49	2848.12	2640.00	-10.32	-7.88
24	3045.29	2980.90	2760.00	-10.34	-8.00
25	3126.37	3061.98	2840.00	-10.08	-7.82
26	3274.03	3209.63	2960.00	-10.61	-8.43
27	3416.46	3352.05	3080.00	-10.92	-8.83
28	3542.47	3478.06	3200.00	-10.70	-9.69
29	3685.03	3620.61	3320.00	-10.99	-9.05
30	3817.29	3752.87	3440.00	-10.97	-9.09
31	3670.99	3806.56	3560.00	-8.74	-6.93
32	3995.57	3931.14	3680.00	-8.58	-6.82
33	4106.90	4042.47	3800.00	-8.08	-6.38
34	4240.94	4176.51	3920.00	-8.19	-6.54
35	4363.48	4299.04	4040.00	-8.01	-6.41
36	4469.17	4404.73	4160.00	-7.43	-5.88
37	4568.06	4503.62	4280.00	-6.73	-5.22
38	4586.87	4522.43	4400.00	-4.25	-2.78

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TR TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	94.94	83.08	64.08	-48.16	-29.65
2	250.66	234.95	182.50	-37.35	-28.74
3	310.44	393.75	298.66	-37.43	-31.84
4	580.74	563.51	417.99	-38.94	-34.81
5	702.22	684.91	535.98	-31.02	-27.79
6	850.06	832.62	651.78	-30.42	-27.75
7	998.04	980.48	767.06	-30.11	-27.82
8	1142.48	1124.83	885.65	-29.00	-27.01
9	1209.03	1191.37	1004.31	-20.38	-18.63
10	1247.76	1230.10	1117.18	-11.69	-10.11
11	1286.28	1268.62	1222.30	-5.23	-3.79

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
TL TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	92.09	82.61	102.25	9.94	19.21
2	202.08	191.00	221.75	8.87	13.87
3	353.30	340.66	338.25	-4.36	-.71
4	533.24	520.45	432.25	-23.36	-20.40
5	696.98	683.99	527.58	-32.11	-29.65
6	889.14	875.94	646.16	-37.60	-35.56
7	1093.64	1080.26	763.66	-43.21	-41.46
8	1290.64	1277.15	882.16	-46.30	-44.78
9	1442.07	1428.55	1000.46	-44.14	-42.79
10	1505.37	1491.85	1117.96	-34.65	-33.44
11	1557.81	1544.28	1196.54	-30.19	-29.06

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
SR TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	91.60	81.06	77.25	-18.57	-4.93
2	243.20	229.88	193.50	-25.69	-18.80
3	290.26	276.90	239.33	-21.28	-15.70
4	415.76	402.10	334.33	-24.36	-20.27
5	582.00	567.96	453.08	-28.45	-25.36
6	736.72	722.52	571.16	-28.99	-26.50
7	892.12	877.79	685.99	-30.05	-27.96
8	1046.34	1031.92	805.91	-29.83	-28.04
9	1191.86	1177.37	923.33	-29.08	-27.51
10	1313.55	1299.03	1018.75	-28.94	-27.51
11	1472.75	1458.22	1115.33	-32.05	-30.74

Appendix A-5 (continued)

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0011
SL TUNNEL
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	SUMMATION
1	77.75	65.82	109.33	28.89	39.80
2	202.23	187.58	225.99	10.51	17.00
3	328.71	313.30	344.91	4.70	9.16
4	455.76	439.99	460.83	1.10	4.52
5	515.55	499.76	526.50	2.08	5.08
6	646.25	630.29	643.75	-0.39	2.09
7	729.48	713.47	734.33	0.66	2.84
8	834.35	818.26	845.66	1.34	3.24
9	870.26	854.16	938.56	7.28	8.99
10	951.38	935.24	1056.06	9.91	11.44
11	1066.42	1050.26	1176.56	9.36	10.73
12	1168.36	1152.16	1295.06	9.78	11.03
13	1257.38	1241.16	1407.90	10.69	11.84
14	1350.79	1334.57	1488.06	9.22	10.31

BAY AREA RAPID TRANSIT DISTRICT
CONTRACT NUMBER 1S0051A
SL TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	SUMMATION
1	285.14	135.57	116.03	-145.75	-16.84
2	430.72	280.31	227.89	-89.00	-23.00
3	553.18	402.48	341.47	-62.00	-17.87
4	645.19	494.40	423.41	-52.38	-16.77
5	739.65	588.78	504.99	-46.47	-16.59
6	877.63	726.59	621.19	-41.28	-16.97
7	1002.85	851.71	737.61	-35.96	-15.47
8	1154.33	1003.09	852.78	-35.36	-17.63
9	1232.30	1081.06	909.25	-35.53	-18.90

BAY AREA RAPID TRANSIT
CONTRACT NUMBER 1S0051A
SR TUNNEL - MARKET STREET
SAN FRANCISCO, CALIFORNIA

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	SUMMATION
1	74.76	50.54	66.00	-13.27	23.42
2	179.52	153.15	183.75	2.30	16.65
3	247.24	220.76	246.42	-0.33	10.44
4	327.71	301.06	323.42	-1.33	6.91
5	437.10	410.19	439.26	0.49	6.62
6	563.74	536.58	557.16	-1.18	3.70
7	657.86	630.61	640.85	-2.65	1.60
8	747.58	720.29	721.45	-3.62	0.16
9	859.73	832.36	836.14	-2.32	0.45
10	894.70	867.33	885.64	-1.02	2.07

UPPER SALT CREEK #1
CONTRACT NUMBER 68-404-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	SUMMATION
1	33.41	28.81	33.50	.28	14.01
2	46.21	41.57	77.50	40.37	46.36
3	112.67	106.80	127.50	11.63	16.24
4	146.69	140.69	176.50	16.89	20.29
5	149.42	143.42	184.50	19.02	22.27
6	172.76	166.76	234.50	26.33	28.89
7	183.73	177.72	264.50	30.54	32.81
8	190.96	184.96	282.50	32.40	34.53
9	219.56	213.54	332.50	33.97	35.78
10	239.22	233.19	371.50	35.61	37.23
11	294.56	288.42	419.50	29.78	31.25
12	329.83	323.67	468.00	29.52	30.84
13	366.11	359.93	514.00	28.77	29.97
14	436.96	430.71	564.00	22.53	23.63
15	500.50	494.21	614.00	18.48	19.51
16	531.20	524.91	658.00	19.27	20.23
17	565.72	559.43	699.50	19.13	20.03
18	576.53	570.23	715.50	19.42	20.30
19	599.03	592.73	765.50	21.75	22.57
20	633.34	627.05	811.50	21.95	22.73
21	677.96	671.66	861.50	21.31	22.04
22	720.67	714.36	911.50	20.94	21.63
23	744.48	738.18	959.50	22.41	23.07
24	797.61	791.30	1007.50	20.83	21.46
25	811.11	804.80	1051.50	22.86	23.46
26	831.18	824.97	1095.50	24.13	24.70
27	877.64	871.32	1142.50	23.18	23.74
28	955.47	949.08	1192.50	19.88	20.41
29	990.03	983.70	1228.50	19.41	19.93
30	1045.67	1039.33	1278.50	18.21	18.71
31	1106.97	1100.63	1328.50	16.68	17.15
32	1143.47	1137.13	1378.50	17.05	17.51
33	1202.43	1196.07	1423.50	15.53	15.98
34	1240.73	1234.38	1461.50	15.11	15.54
35	1304.00	1297.64	1501.50	13.15	13.58
36	1340.08	1333.72	1539.50	12.95	13.37
37	1383.85	1377.48	1587.50	12.83	13.23
38	1428.91	1422.55	1637.50	12.74	13.13
39	1486.90	1460.53	1687.50	11.89	12.27
40	1558.06	1551.69	1737.50	10.33	10.69
41	1609.31	1602.94	1787.50	9.97	10.33
42	1640.78	1634.41	1837.50	10.71	11.05
43	1656.82	1650.45	1885.50	12.13	12.47
44	1667.92	1661.55	1929.50	13.56	13.89
45	1683.42	1677.05	1975.50	14.78	15.11
46	1717.72	1711.35	2023.50	15.11	15.43
47	1776.19	1769.82	2071.50	14.26	14.56
48	1831.90	1825.52	2121.50	13.65	13.95

Appendix A-5 (continued)

UPPER SALT CREEK #2
CONTRACT NUMBER 68-405-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	23.65	19.80	40.00	40.87	50.50
2	30.95	27.08	57.00	45.70	52.49
3	57.57	53.31	103.00	44.10	48.24
4	105.54	100.86	149.00	29.16	32.31
5	206.88	201.14	212.00	2.41	5.12
6	231.81	226.06	252.00	8.01	10.29
7	417.44	411.55	319.00	-30.86	-29.01
8	453.15	447.25	363.00	-24.84	-23.21
9	511.41	505.47	416.00	-22.94	-21.51
10	575.39	569.40	476.00	-20.88	-19.62
11	585.89	579.89	494.00	-16.60	-17.39
12	636.68	630.67	538.00	-18.34	-17.22
13	673.28	667.26	586.00	-14.89	-13.87
14	717.33	711.30	629.00	-14.04	-13.08
15	776.13	770.09	669.00	-16.01	-15.11
16	827.84	821.80	703.00	-17.76	-16.90

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	97.26	86.60	88.50	-9.90	2.14
2	146.70	135.87	122.50	-19.76	-10.92
3	344.48	331.59	215.00	-60.22	-54.23
4	398.74	385.84	242.00	-64.77	-59.44
5	577.12	563.69	315.50	-82.92	-78.67
6	614.22	600.79	342.00	-79.60	-75.67
7	615.61	602.18	349.50	-76.14	-72.30
8	683.28	669.83	398.00	-71.68	-68.30
9	769.59	756.12	492.50	-56.26	-53.53
10	946.97	935.34	600.50	-58.03	-55.76
11	1136.37	1124.61	711.00	-60.11	-58.17
12	1149.32	1135.56	728.50	-57.77	-55.88

UPPER SALT CREEK #3
CONTRACT NUMBER 68-406-25
CHICAGO, ILLINOIS

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	22.68	19.24	40.00	43.30	51.89
2	63.11	58.40	80.00	21.11	27.00
3	142.39	136.89	120.00	-18.66	-14.08
4	180.63	175.07	160.00	-12.89	-9.42
5	218.54	212.93	200.00	-9.27	-6.47
6	257.06	251.42	223.00	-15.27	-12.75
7	329.29	323.43	263.00	-25.21	-23.05
8	369.01	363.29	303.00	-28.39	-26.50
9	438.98	433.26	343.00	-27.98	-26.31
10	480.92	475.19	383.00	-25.57	-24.07
11	501.05	495.32	423.00	-18.45	-17.10
12	536.21	530.47	463.00	-15.81	-14.57
13	576.96	571.22	500.00	-15.39	-14.24
14	600.33	594.58	532.00	-12.84	-11.76
15	649.77	644.01	564.00	-15.21	-14.19
16	708.23	702.46	604.00	-17.26	-16.30
17	752.89	747.11	644.00	-16.91	-16.01
18	609.33	603.54	684.00	-18.32	-17.48
19	658.08	652.29	724.00	-18.52	-17.72
20	915.97	910.16	764.00	-19.89	-19.13
21	949.51	943.70	804.00	-18.10	-17.38
22	1007.78	1001.96	844.00	-19.40	-18.72
23	1048.65	1042.83	884.00	-18.63	-17.97
24	1070.49	1064.67	924.00	-15.85	-15.22
25	1083.57	1077.70	964.00	-12.40	-11.79
26	1106.67	1100.85	1004.00	-10.23	-9.65
27	1147.09	1141.27	1044.00	-9.87	-9.32
28	1190.85	1185.03	1064.00	-9.86	-9.32
29	1226.77	1222.94	1124.00	-9.32	-8.80

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A PENTAGON INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	21.27	18.87	9.50	-123.93	-98.68
2	34.53	32.06	17.78	-94.22	-80.33
3	74.02	71.06	56.78	-30.36	-25.14
4	78.31	75.34	66.78	-17.26	-12.82
5	102.66	99.66	98.28	-4.46	-1.41
6	146.65	145.49	139.28	-6.73	-4.46
7	212.36	209.00	181.78	-16.82	-14.98
8	249.87	246.49	207.28	-20.55	-18.92
9	296.15	292.74	240.78	-23.00	-21.58
10	331.97	328.55	281.78	-17.81	-16.60
11	371.57	368.14	326.78	-13.71	-12.66
12	524.72	521.03	427.78	-22.66	-21.80
13	749.71	745.72	504.28	-48.67	-47.88
14	906.06	901.99	593.28	-52.72	-52.03
15	967.07	962.99	642.78	-50.45	-49.62
16	1033.09	1028.99	714.28	-44.63	-44.06
17	1050.56	1046.48	732.78	-43.37	-42.81
18	1052.26	1048.16	741.78	-41.86	-41.31
19	1122.69	1118.59	837.28	-34.09	-33.60
20	1224.83	1220.71	931.78	-31.45	-31.01
21	1351.74	1347.59	1032.28	-30.95	-30.55

Appendix A-5 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS- ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	102.71	90.16	56.50	-81.78	-59.57
2	233.62	219.10	149.00	-56.80	-47.05
3	256.10	241.58	183.50	-39.57	-31.65
4	271.25	256.72	200.00	-35.62	-28.36
5	419.18	403.97	274.00	-52.99	-47.43
6	516.42	501.09	328.50	-57.21	-52.54
7	677.59	661.98	422.50	-60.39	-56.68
8	778.19	762.53	513.00	-51.69	-48.64
9	943.95	928.14	621.50	-51.88	-49.34
10	1084.94	1069.07	730.00	-48.62	-46.45
11	1214.71	1198.79	832.50	-45.91	-44.00
12	1357.38	1341.41	916.00	-48.19	-46.44
13	1494.92	1478.92	989.50	-51.08	-49.46
14	1580.76	1564.75	1082.00	-46.10	-44.62
15	1600.50	1584.49	1135.50	-40.95	-39.54
16	1625.54	1609.53	1180.50	-37.70	-36.34

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1FC012
F1B NORTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS- ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	34.65	32.12	39.00	11.16	17.63
2	66.84	64.15	64.00	20.43	23.63
3	188.32	184.12	160.00	-17.70	-15.08
4	351.11	346.25	256.00	-37.15	-35.25
5	430.58	425.68	348.50	-23.55	-22.14
6	470.19	465.28	392.00	-19.95	-18.69
7	534.21	529.26	478.00	-11.76	-10.73
8	618.60	613.64	581.50	-6.38	-5.53
9	640.93	635.98	638.50	-.38	.39
10	694.33	689.37	705.00	1.51	2.22
11	715.84	710.87	755.00	5.19	5.84
12	768.56	763.59	812.00	5.35	5.96
13	825.17	820.20	869.00	5.04	5.62
14	887.01	882.04	926.00	4.21	4.75
15	905.96	900.99	945.00	4.13	4.66

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0021
F2A BRANCH ROUTE INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS- ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	48.25	42.64	17.50	-175.73	-143.68
2	164.20	154.67	104.00	-57.89	-48.72
3	205.09	195.50	139.00	-47.55	-40.65
4	354.53	343.55	237.50	-49.28	-44.65
5	487.10	475.73	336.00	-44.97	-41.59
6	588.77	577.28	399.50	-47.38	-44.50
7	762.59	750.79	511.00	-49.23	-46.93
8	924.33	912.38	619.50	-49.21	-47.28
9	1097.72	1085.67	728.00	-50.79	-49.13
10	1153.96	1141.91	801.00	-44.06	-42.56
11	1270.26	1258.19	901.50	-40.90	-39.57
12	1380.29	1368.20	1010.00	-36.66	-35.47
13	1498.13	1486.02	1100.00	-36.19	-35.09
14	1575.10	1562.99	1193.00	-32.03	-31.01
15	1590.07	1577.96	1235.50	-28.70	-27.72
16	1693.15	1681.02	1368.50	-23.72	-22.84
17	1725.75	1713.63	1421.50	-21.40	-20.55

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F1B NORTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS- ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	59.68	54.10	56.00	-6.57	3.38
2	223.24	213.56	128.00	-74.40	-66.85
3	331.17	321.21	208.50	-58.83	-54.06
4	404.90	394.90	265.00	-52.79	-49.02
5	477.62	467.59	331.50	-44.08	-41.05
6	504.62	494.59	407.50	-23.83	-21.37
7	549.17	539.13	476.70	-15.20	-13.10
8	612.91	602.86	562.70	-8.92	-7.14
9	717.80	707.70	658.20	-9.05	-7.52
10	802.94	792.82	722.70	-11.10	-9.70
11	869.49	859.36	787.20	-10.45	-9.17
12	890.46	880.33	814.70	-9.30	-8.06

Appendix A-5 (continued)

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F18 SOUTH OUTBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	25.05	23.34	16.00	-56.55	-45.85
2	66.04	63.86	56.00	-17.94	-14.03
3	94.56	92.32	80.00	-18.20	-15.40
4	146.97	144.57	113.00	-30.06	-27.94
5	219.28	216.71	177.00	-23.89	-22.44
6	291.27	288.62	254.50	-14.45	-13.41
7	370.18	367.45	332.00	-11.50	-10.68
8	447.98	445.21	435.50	-2.86	-2.23
9	509.83	507.05	507.00	-.56	-.01
10	521.90	519.12	523.00	.21	.74
11	542.49	539.71	554.00	2.08	2.58
12	598.67	595.88	623.50	3.98	4.43
13	651.72	648.92	701.00	7.03	7.43
14	666.51	663.71	724.50	8.00	8.39
15	698.46	695.66	787.00	11.25	11.61
16	766.88	764.07	872.50	12.11	12.43
17	850.69	847.87	960.00	11.39	11.68
18	899.43	896.61	1030.00	12.68	12.95
19	975.92	973.10	1117.50	12.67	12.92
20	1066.88	1064.04	1255.50	15.02	15.25
21	1159.56	1156.71	1358.00	14.61	14.82
22	1231.40	1228.55	1434.00	14.13	14.33
23	1307.47	1304.61	1520.00	13.98	14.17
24	1399.56	1396.70	1615.50	13.37	13.54
25	1490.37	1487.51	1711.00	12.89	13.06

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 1F0012
F18 SOUTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	99.87	93.04	71.50	-39.68	-30.12
2	175.07	167.92	169.50	-3.26	.93
3	276.53	269.14	257.00	-7.60	-4.72
4	405.92	398.70	343.00	-18.34	-16.12
5	545.62	537.86	430.50	-26.74	-24.94
6	614.91	607.13	487.00	-26.26	-24.67
7	721.97	714.17	575.00	-25.56	-24.20
8	641.68	833.85	668.50	-25.91	-24.73
9	946.46	938.60	767.50	-23.32	-22.29
10	1040.56	1032.69	859.50	-21.07	-20.15
11	1130.19	1122.32	943.50	-19.79	-18.95
12	1215.55	1207.67	1031.00	-17.90	-17.14
13	1284.93	1277.05	1113.00	-15.45	-14.74
14	1335.07	1327.19	1179.50	-13.19	-12.52

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
CONTRACT NUMBER 100091
D-9 SOUTH INBOUND
WASHINGTON, D.C.

WEEK	CUMULATIVE HOURS CALCULATED INTEGRATION	CUMULATIVE HOURS CALCULATED SUMMATION	CUMULATIVE HOURS-ACTUAL	% DIFFERENCE INTEGRATION	% DIFFERENCE SUMMATION
1	75.48	68.55	96.00	21.38	28.59
2	226.91	217.23	213.00	-6.53	-1.98
3	395.15	384.71	332.50	-18.84	-15.70
4	515.93	505.35	462.50	-11.55	-9.27
5	614.30	603.67	569.50	-7.87	-6.00
6	763.44	752.66	704.50	-8.37	-6.84
7	887.67	876.87	834.50	-6.37	-5.06
8	984.16	973.33	949.50	-3.65	-2.51
9	1012.73	1001.90	987.50	-2.55	-1.46

Appendix A-5 (continued)

Appendix A-6

The format of the keypunch cards used to record the weekly progress data from which the various equations were derived.

Variable meanings and values assigned are as follows. The dotted line represents the decimal point; the format is 7F10.5.

Variable No.	Description
1	The survey station at the beginning of the week's tunneling.
2	Lineal feet tunneled during the week.
3	Cumulative feet tunneled through the end of the week.
4	Tunneling hours during the week from Ring Logs.
5	Tunneling down hours in week due to shield and its ancillaries' failure.
6	Down hours in week due to excavating equipment; e.g., the rotating wheel and digger arm.
7	Down hours in week due to the conveyor belt.
8	Down hours in week due to muck transportation and/or the bringing in of necessary supplies; e.g., primary lining rings.
9	Down hours in week due to other work causes.
10	Down hours in week due to administrative decision; e.g., a shutdown for surveyor's alignment.
11	Total shift hours in week. Tunneling hours (4) plus down hours (5 + 6 + 7 + 8 + 9 + 10) = total shift hours.

Variable No.	Description
	Note: In some cases, tunneling did not begin immediately at the beginning of the week's first shift and frequently shutdown earlier than the end of the week's last shift. Where this was known, the interim time was assigned to administrative down hours (10). Where actual week's beginning and end times were unknown, the week's total shift hours were computed between the time for the first shove and the last ring erection.
12	Fraction of the face as silt and clay +1.
13	Fraction of the face as clay and sand +1.
14	Fraction of the face as sand and gravel +1.
15	Fraction of the face as cobbles and boulders + 1.
16	Fraction of the face as cemented ground +1.
17	Fraction of the face as peat and trash + 1.
18	Fraction of the face as cohesive ground + 1.
	Note: The sum of the fractions logged for variables 12, 13, 14, 15, and 17 should equal 1.
19	Average tunnel pressure during the week-psig.
20	A measure of the average wetness in the tunnel during the week. Refer to Section 4.2. The range is from 1.0 to 2.0.
21	Driver horsepower to cutting wheel or digger arms. These data were not complete and therefore the variable was not used in the equation derivations.
22	Total jacking potential of shield in short tons (2000 lb/ton). In some cases, the jacking potential was greater than the ring strength; a relief valve was installed in the hydraulic line to reduce the pressure. The reduced pressure is to be used in calculating the jacking potential tons.

Variable No.	Description
23	Outside diameter of shield - ft.
24	If a rotating wheel excavator is used = 2, otherwise = 1.
25	If an oscillating wheel excavator is used = 2, otherwise = 1. None of the tunnels investigated used this equipment.
26	If a digger arm excavator is used = 2, otherwise = 1.
27	If manual excavation is used = 2, otherwise = 1.
	Note: In some tunnels, intial excavation was manual (2 logged) until the digger arm could be brought to bear. Then, due to the limited radius of the arm, excavation was 50 percent manual (1.5 logged) and 50 percent digger arm (1.5 logged).
28	If a conveyor belt and train are used = 2, otherwise = 1.
29	If a conveyor belt and truck are used = 2, otherwise =1.
30	If a rubber tired mucking truck is used = 2, otherwise = 1.
31	Fraction of the face as non-cohesive ground + 1. (This variable was eliminated as being the converse of variable 18.)
32	Fraction of the face as running ground + 1.
33	If ribs and lagging primary lining is used = 2, otherwise = 1.
34	If concrete pipe lining is jacked into place = 2, otherwise = 1.
36	If it was the last week of tunneling = 1, otherwise = 0. This was an added variable, and it was not practical to redo all the data sets to add a 1 or a 2. A 1 was added to all data sets for just the last week. During the computer data processing, a 1 was added to all number 36 variables so that the 1/2 relation would hold.
38	The tunnel RoA intercept. See Section 5.2.
39	The hours/ft for the shove operation. See Section 4.4.
40	The hours/ft for the ring erection. See Section 4.4.

Variable No.	Description
41	The hours/ft for the dead time. See Section 4.4. Note: The data for variables 39, 40, and 41 were only obtained for tunnels in which the original ring logs were used for tunneling advance rates.
42	The learning curve RoA exponent. See Section 5.2.

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
DOT STUDY

DATA PROCESSING — KEYPUNCH CODING FORM–GENERAL

Job No.: 11770-100 | Program No.: Tunnel No:

Tunnel Location;

Tunnel Contract No: .

Page 1 of 6

CODING CONVENTIONS

0 ZERO, Ø ALPHA | 1 ONE, I ALPHA | 2 TWO, Z ALPHA | 5 FIVE, S ALPHA | U - YU, V - VEE

① Station Begin of Week	② Tunnel Rate Ft/Wk	③ Cum. Ft. of Tunnel	④ Tunneling Hrs in Week	⑤ Shield Dwn Time Hrs/Wk	⑥ Excav. Equip. Dwn Time - Hr/Wk	⑦ Conveyor Dwn Time - Hr/Wk	Card No.	Data Set No.	Tnl. No.

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
DOT STUDY

DATA PROCESSING — KEYPUNCH CODING FORM–GENERAL

Job No.: 11770-100 | Program No.: Tunnel No:

Tunnel Location;

Tunnel Contract No: .

Page 2 of 6

CODING CONVENTIONS

0 ZERO, Ø ALPHA | 1 ONE, I ALPHA | 2 TWO, Z ALPHA | 5 FIVE, S ALPHA | U - YU, V - VEE

No/Yes = 1/2

⑧ Muck Transport Dwn Time - Hr/Wk	⑨ Misc. Dwn Time Hr/Wk	⑩ Admin. Dwn Time - Hr/Wk	⑪ Total Shift Time Hr/Wk	⑫ Grnd: Silt & Clay N/Y	⑬ Grnd: Clay & Sand N/Y	⑭ Grnd: Sand & Gravel N/Y	Card No.	Data Set No.	Tnl. No.

Appendix A-6 Keypunch Forms

BECHTEL

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
DOT STUDY
DATA PROCESSING — KEYPUNCH CODING FORM—GENERAL

JOB NO.	PROGRAM NO.
11770-100	Tunnel No:
Tunnel Location:	
Tunnel Contract No:	
PAGE 3 of 6	

CODING CONVENTIONS

0 - ZERO	1 - ONE	2 - TWO	5 - FIVE	U - YU
Ø - ALPHA	I - ALPHA	Z - ALPHA	S - ALPHA	V - VEE

15) Grnd: Cbls & Boulders N/K	16) Grnd: Cemented N/K	17) Grnd: Peat & Trash N/K	18) Grnd: Cohesive N/K	19) Tunnel Pressure psig	20) Flowing H2O @ Face: 1→2 N/K	21) Hp to Cutter/ Digger	Card No.	Data Set No.	Tnl. No.

00130 (5-75)

BECHTEL

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
DOT STUDY
DATA PROCESSING — KEYPUNCH CODING FORM—GENERAL

JOB NO.	PROGRAM NO.
11770-100	Tunnel No:
Tunnel Location:	
Tunnel Contract No:	
PAGE 4 of 6	

CODING CONVENTIONS

0 - ZERO	1 - ONE	2 - TWO	5 - FIVE	U - YU
Ø - ALPHA	I - ALPHA	Z - ALPHA	S - ALPHA	V - VEE

22) Total Jacking Potential of Shield-Tons	23) OD of Shield - ft.	24) Shield + Rotating Wheel - N/K	25) Shield + Oscill. Arms - N/K	26) Shield + Digger Arm - N/K	27) Shield + Man. Digging - N/K	28) Mcking Equip: Conv. Belt + Train: N/K	Card No.	Data Set No.	Tnl. No.

00130 (5-75)

Appendix A-6 (Continued)

BECHTEL

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
DOT STUDY

DATA PROCESSING — KEYPUNCH CODING FORM—GENERAL

JOB NO.	PROGRAM NO.
11770-100	Tunnel No:
PROGRAM: Tunnel Location:	
Tunnel Contract No:	
CODER / DATE	PAGE 5 OF 6

CODING CONVENTIONS

0 = ZERO	1 = ONE	2 = TWO	5 = FIVE	U = YU
Ø = ALPHA	I = ALPHA	Z = ALPHA	S = ALPHA	V = VEE

29) Mckng Equip: Conv. Belt + Trck - N/Y	30) Mckng Equip. - Rbr. Tired Trk - N/Y	31) Grnd: Non-Cohesive: 1→2	32) Grnd: Running: 1→2	33) Primary Lining: Ribs & Lagging: 1/2	34) Prim. Lining: Conc. Apo Inhibit Ibra 1/2	35)	Card No.	Data Set No.	Tnl. No.

00130 (5-75)

ECONOMIC FACTORS IN TUNNEL CONSTRUCTION
DOT STUDY

DATA PROCESSING — KEYPUNCH CODING FORM—GENERAL

JOB NO.	PROGRAM NO.
11770-100	Tunnel No:
PROGRAM: Tunnel Location;	
Tunnel Contract No:	
CODER / DATE	PAGE 6 OF 6

CODING CONVENTIONS

0 = ZERO	1 = ONE	2 = TWO	5 = FIVE	U = YU
Ø = ALPHA	I = ALPHA	Z = ALPHA	S = ALPHA	V = VEE

36) Lost Wk Tunneling ≥ 1	37)	38) Learning Curve Intercept	39) Hr/Ft Shove	40) Hr/Ft Ring Erection	41) Hr/Ft Dead Time	42) Total Cycle L.C. Exponent	Card No.	Data Set No.	Tnl. No.

00130 (5-75)

Appendix A-6 (Continued)

Appendix B

MEXICO CITY TUNNEL DATA

In this appendix, the data submitted by the contractor who conducted the tunneling effort for the Mexico City deep sewer (Ingenieros Civiles Asociados, S.A.) are presented for reference. It is felt that the data herein may be of value either to support or lead to modification of the equations derived in this report.

November 11, 1976

Bechtel Corporation
Fifty Beal Street
San Francisco, California
94119 U.S.A.

Attention: Mr. L.R. Damskey, Long Range Planning

In response to your wishes, we are sending you a report detailing the incidents during the period of excavation in one of the tunnels which we are drilling in the soils of Mexico City.

The adjoined information contains the details requested of us during your stay in this city and constitutes the complement to the data supplied earlier.

We would be grateful if, at the conclusion of your investigations, you would send us a copy of the final result of your studies.

Respectfully,

Engineer Manuel Salvoch
Director

7. THE DRAINAGE PLAN

In this plot of land, it was necessary to proceed with a deep reduction of the level of the ground waters, in virtue of the fact that this level was localized at 10.0 m above the crown of the tunnel. Not to dewater this would have presented serious problems of piping in the sandy matter especially. The surface or deep-well type dewatering system covers 60 m ahead of and 40 m behind the face. It was made up of 15 shafts on the average and the capacity of the battery of pumps was 80 to 100 liters/each. The system remained installed and functioning for at least fifteen days previous to when the tunnel would pass through the corresponding zone and was maintained for the necessary time until the primary revetment of the concrete grout would be injected in its periphery.

In Figure B-1 is shown a plan of the line for lowering the level of the water by pump.

In Figure B-2 is presented a cross-section of a typical pump-shaft.

A. DESCRIPTION: CASE HISTORY DATA

1. PROJECT NAME: Federal District Deep Drainage

2. LOCATION: CENTRAL INTERCEPT TUNNEL: SHAFT AREA 11 - SHAFT 13; excavation with shield stage.

3. OWNER: Head Office of Hydraulic Works of the Department of D.F.

4. CONTRACTOR: TUNEL, S.A. de C.V.

5. DATES: START: 9/25/72 COMPLETE: 11/7/73

6. PROJECT SCOPE (INCLUDE ANY APPURTENANT STRUCTURES): The Federal District Deep Drainage System consists of a complex of tunnels which conduct by gravity the sewerage and rain waters from the Mexico Valley basin to a distant river in the state of Hidalgo. It is made up on two ancillary tunnels: the Central Intercept and the East Intercept, which unite in one major tunnel: the Central Emission tunnel (See plan I-2-5 annexed). The present report refers only to the stage of excavation with the shield, in alluvial soils in Mexico City, from the face of shaft 11 toward shaft 13 of the Central Intercept.

7. OWNER FURNISHED MATERIAL AND EQUIPMENT LIST

Concrete grout
Steel for reinforcement
Type II cement
Tubing for the conductance of compressed air
Rails
Metal frames for shoring
Transformers for the electric current
Electric energy

8. OTHER OWNER SUPPLIED ITEMS (e.g. INSURANCE)

Materials laboratory

B. DESIGN INFORMATION

1. PLAN AND PROFILE ATTACHED:	YES	NO
2. TYPICAL SECTION DRAWING ATTACHED:	YES	NO
3. TEMPORARY LINING DETAILS ATTACHED:	YES	NO
4. PERMANENT LINING DETAILS ATTACHED:	YES	NO
5. GEOLOGICAL PROFILE ATTACHED:	YES	NO

6. VERBAL DESCRIPTION OF SOIL CONDITIONS: Alluvial soils characteristic of Mexico City in its section named the transition zone. In this zone there are in general on the surface clay deposits and organic silts, covering very compressible clay volcanic strata of variable thickness interspersed with beds of compact silty sand or clear sand, which rest upon stiff layers in which the predominating substance is sand or silt. The natural water content in the clay formations and in the sandy silt is, on the argillaceous average, 200% and 40% respectively, displaying cohesion (obtained by means of simple cohesion tests) of 0.4 kg/cm^2 for the former and 0.3 and 0.6 kg/cm^2 for the latter.

7. DEWATERING PLAN ATTACHED: YES NO

8. GROUND WATER CONDITIONS DESCRIPTION: The normal level of ground water in the excavation zone of the tunnel is 10 meters above the crown. With the system of well-shafts this was brought down to below the tunnel invert. In spite of this system, in some sites with sandy substance, the use of WELL POINTS became necessary on the periphery of the face of the tunnel in order to channel the water deposits and remove them by pumping through the tunnel to the surface.

9. SITE PREPARATION AND RESTORATION DESCRIPTION: On the surface the CONTRACTOR supplied the land areas required for the installation of the deep well pumping system, since the project was localized for an inundation of Mexico City. Also, in the access shafts he supplied an area for the installations; towers, mantle capstans, offices, workshops, and storage grounds.

10. UNDERPINNING DESCRIPTION

11. UTILITIES DESCRIPTION: The tunnel remains localized at an average depth of 30.0 m. As a result it passes much below the municipal service lines so that there would not be a problem of relocation of the installations.

C. CONSTRUCTION METHODS

DESCRIPTIONS: The entire length considered in the present report was excavated in normal atmospheric pressure conditions. It was carried out by means of an open face shield of 6.42 m external diameter and 6.40 m length, with remote control hydraulic operation. In the rear it has a thrust system made up of 26 hydraulic jacks at 200 ton capacity each, which operate by resting against the primary revetment. In the front the shield bears 17 jacks with a capacity of 120 tons each, whose function is to hold the wood strut which supports the face.
By means of pneumatic hammers operating manually the material of the face is loosened and falls to a lower central compartment, whence it is removed by an EIMCO 40 H air mucker of 1 m2 capacity mounted above platforms above the track. Then the convoy is pulled by a locomotive up to the shaft through which the muck is lifted to the surface, and from there is transported to the storage beds in back loader trucks (See Fig. B-3).

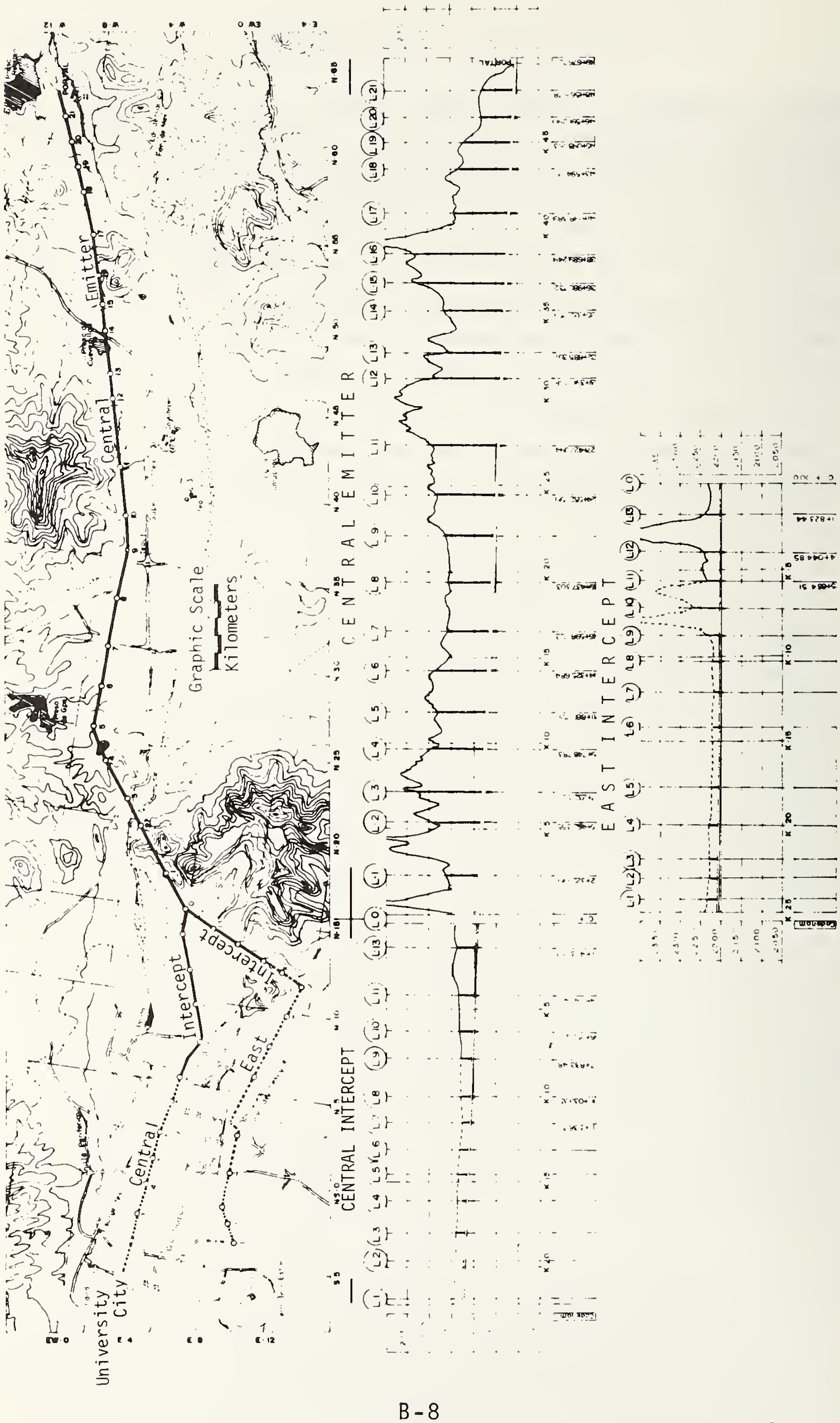
TEMPORARY LINING:

As the shield advances there is put into place the primary revetment, constituted of eleven segments of prefabricated reinforced concrete 1.50 m. long, 0.20 m. thick, and 0.75 cm. wide, which are connected with each other and with the preceding rings by means of screws and nuts, with which they reckon on the necessary cavities and ductile areas. In order to maintain the circular ring, it is propped up with tubular scaffolding equipped with machanical jacks for its adjustment. This support is maintained unitl the zone is injected.

The segmented ring is set up with the aid of an eractor arm behind the shield's jacket, which has a thickness of 5 cm. Consequently, the advance of the shield leaves a void which is refilled immediately with gravel, applied with a small pneumatic conveyor.

Ten meters behind the shield there takes place the process of injection of the cement grout in its refill or consolidation stage, later to pass on to the impermeability stage.

FINAL LINING: The tunnel bears a definitive revetment of concrete filtered on the site, maintaining a final surface of 5.00 mts. diameter. To make this a metallic frame formed by 9 telescopic sections 7.32 m. long, each is utilized. See Fig. B-4. The concrete is produced on the surface, lowered down the tunnel by gravity, loaded onto transport carts (See Fig. B-5), carried to the face, unloaded with the transport belt, fed into pneumatic conveyors, pumped, and filtered (See Fig. B-6).


University City
Central
Intercept
East
Emitter
Graphic Scale
Kilometers
CENTRAL EMITTER
EAST INTERCEPT
CENTRAL INTERCEPT
PORTAL

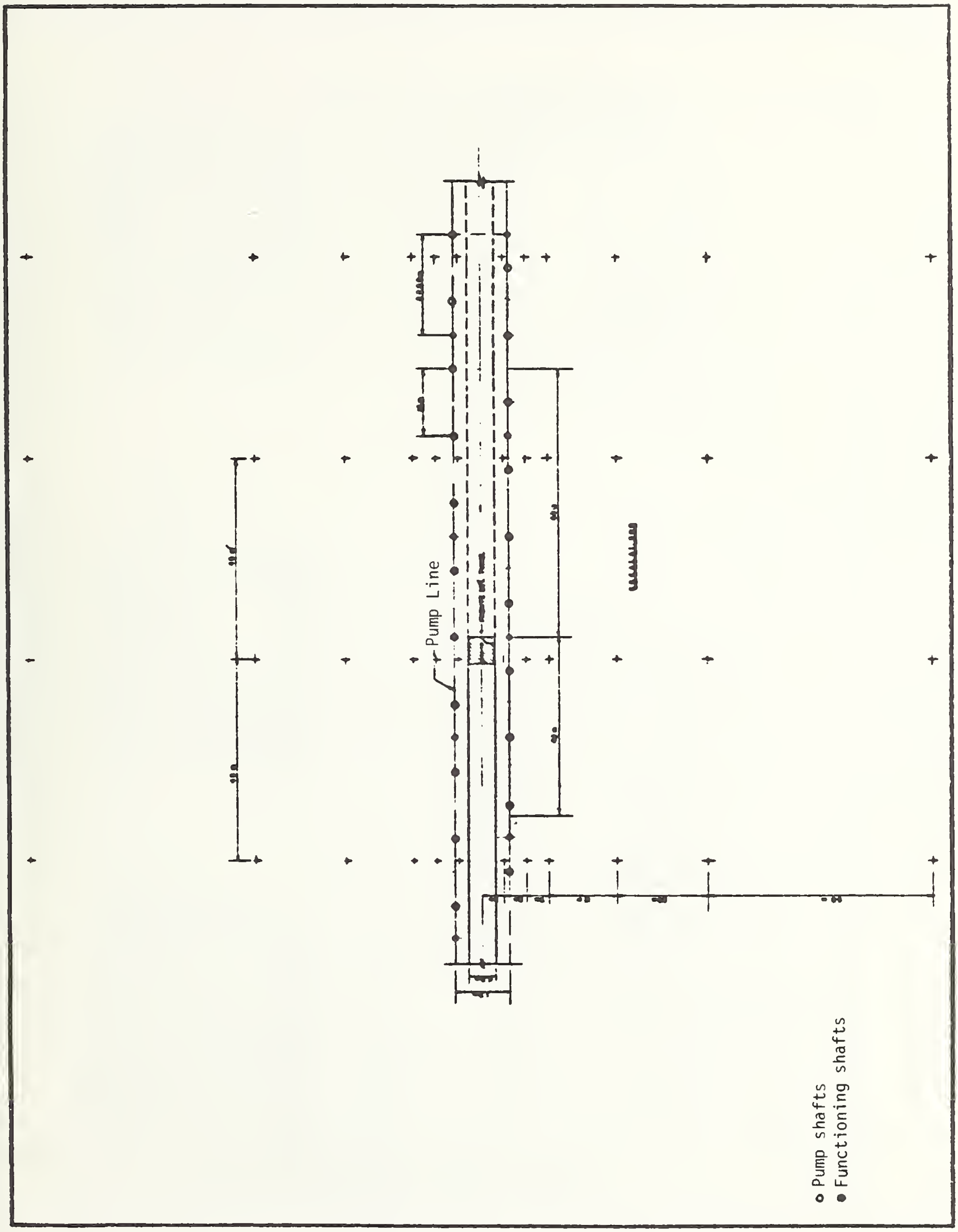


FIGURE B-1. PUMPING AND INSTRUMENTATION PLAN

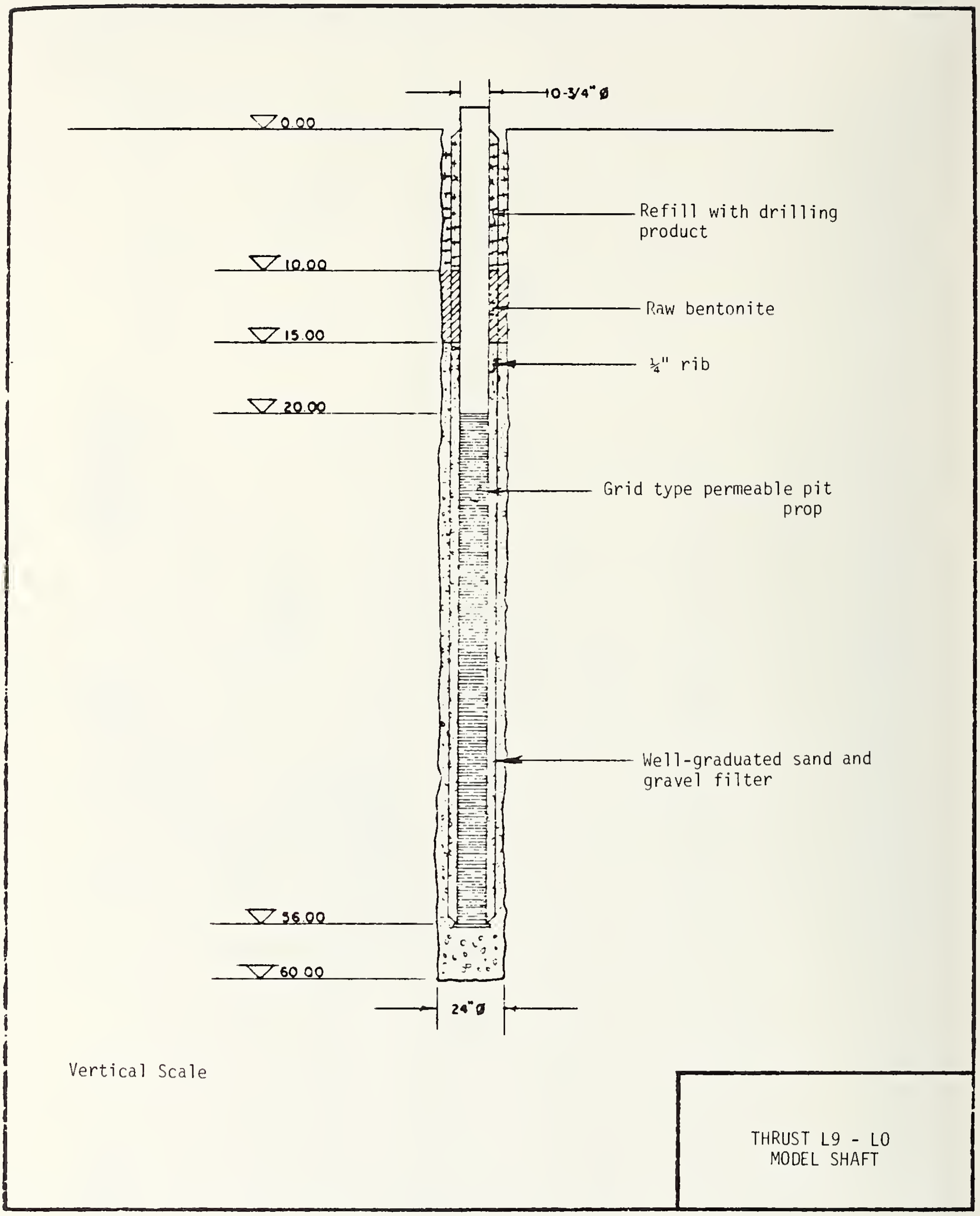


FIGURE B-2. CENTRAL INTERCEPT

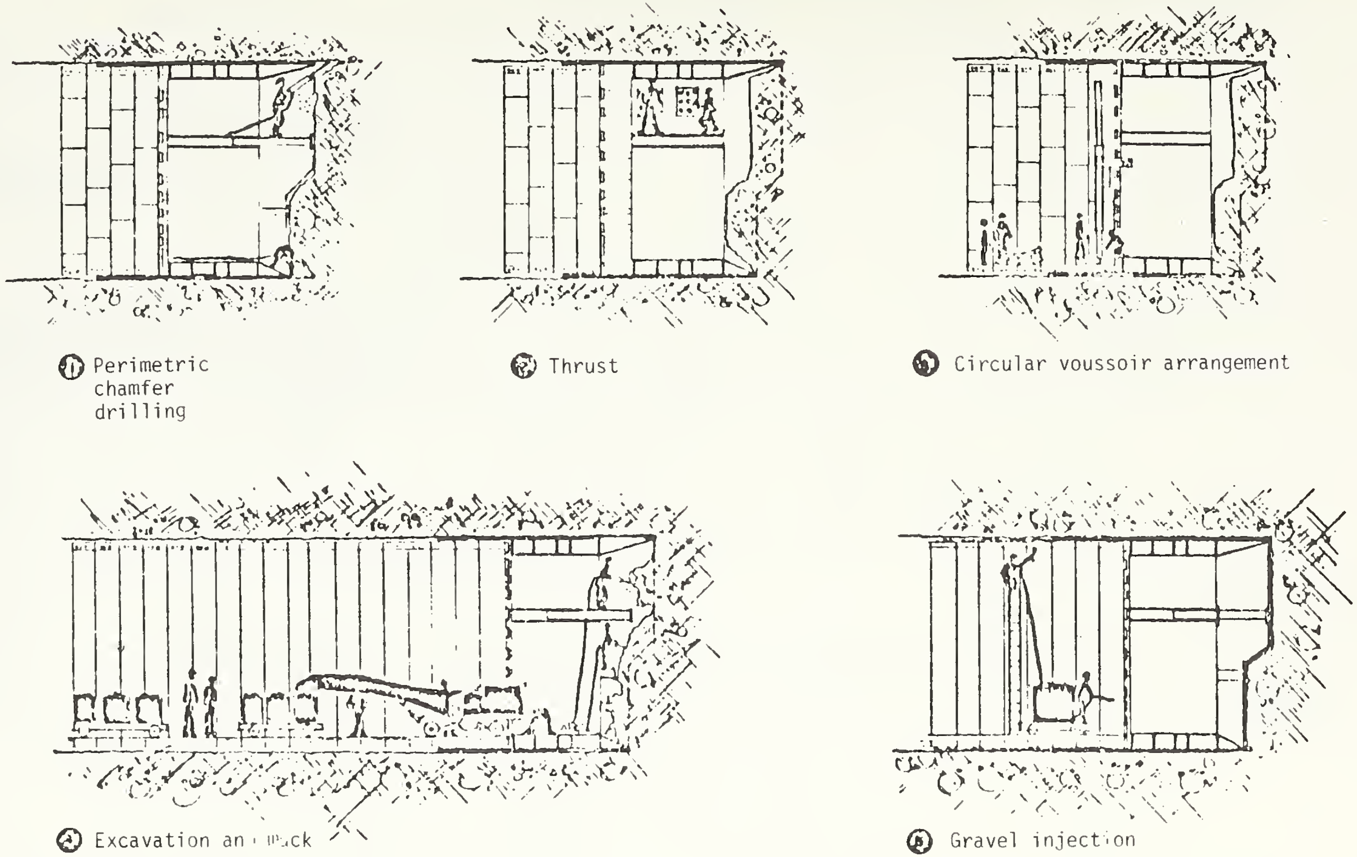


FIGURE B-3. CENTRAL INTERCEPT

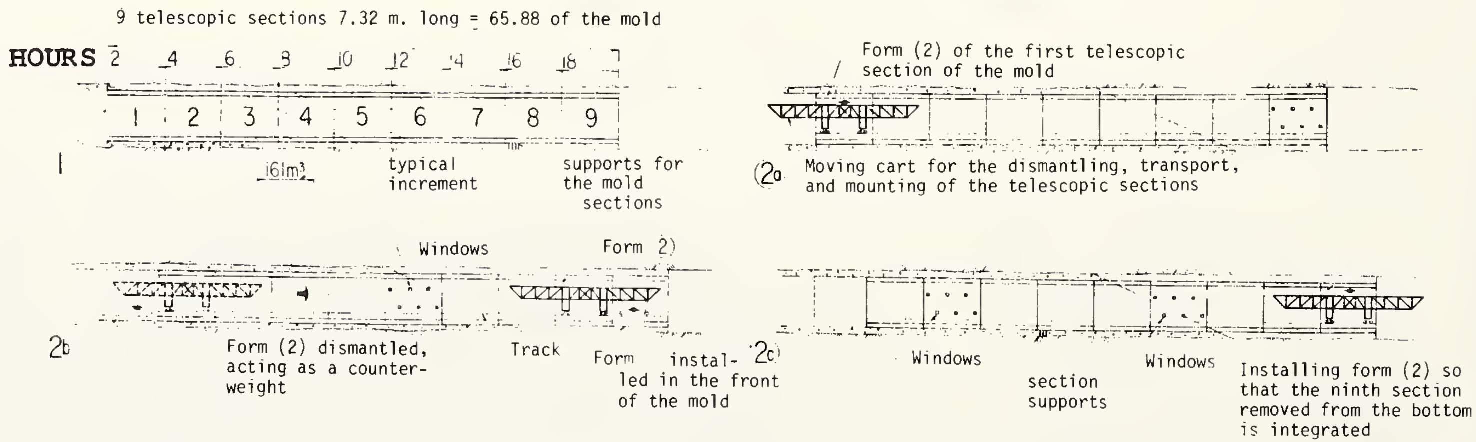


FIGURE B-4. FILTERING RHYTHM AND MOVEMENT SEQUENCE OF THE MOLD SECTIONS

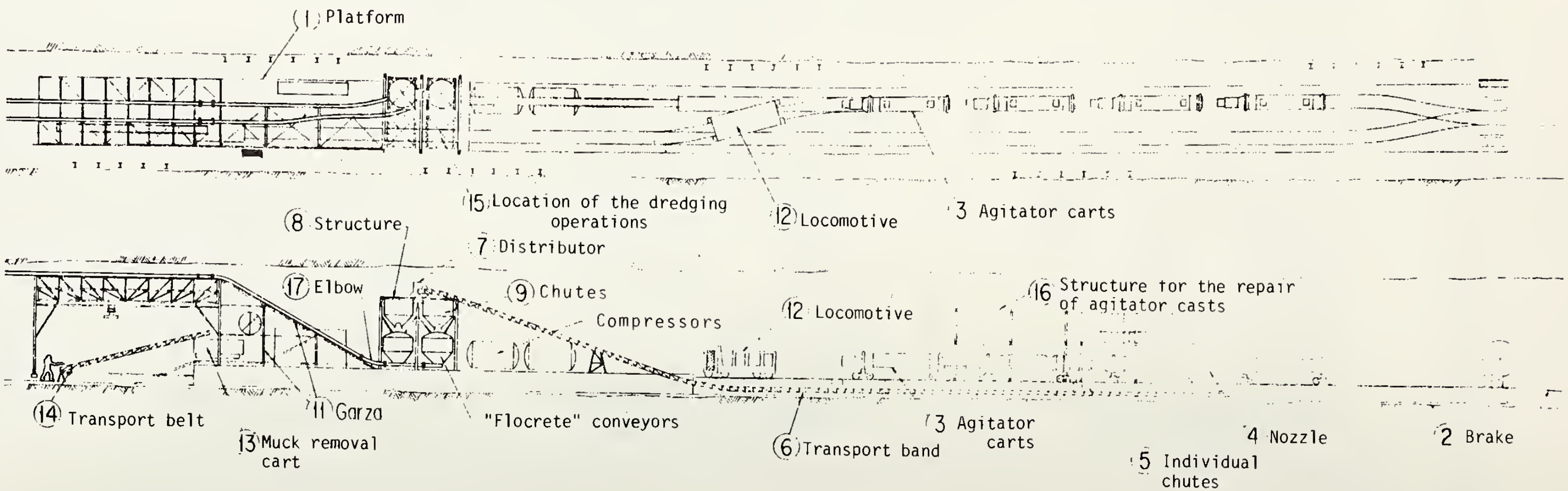


FIGURE B-6. FILTER TRAIN

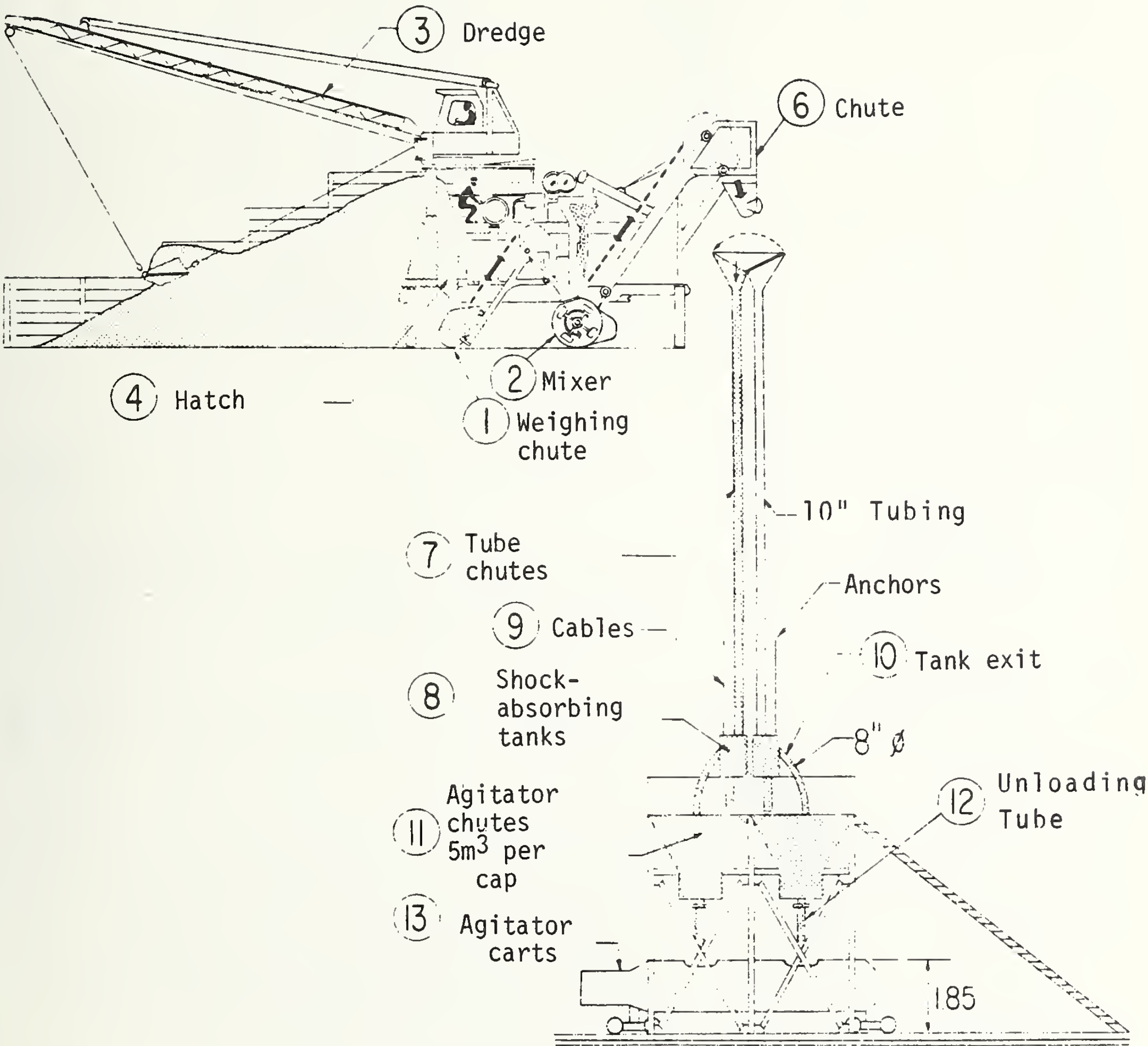


FIGURE B-5. PRODUCING AND UNLOADING OF THE CONCRETE

SHAFT FACE 11 - SHAFT 13 OF THE CENTRAL INTERCEPT

Date	Chain	Advance m/wk	Cumulative advance m/wk	Effective excavation work time hours/wk	LOST TIME: Breakdown in the shield (hr/wk)	LOST TIME: Breakdown in the muck removal system (hr/wk)	LOST TIME: Due to neither personnel nor equipment hr/wk	Amount of water in the face (*)	OBSERVATIONS
23-IX-72	0+104.12								
30-IX-72	0+115.37	11.25	11.25	84			60	2.00	
7-X-72	0+138.12	22.75	34.00	120			24	1.75	
14-X-72	0+161.73	23.61	57.61	126			18	1.75	
21-X-72	0+169.23	7.50	65.11	40		104		1.75	Installation of California switch and accomodation into the track
28-X-72	0+194.73	25.50	90.61	132		12		1.75	
4-XI-72	0+221.73	27.00	117.61	144				1.75	
11-XI-72	0+250.98	29.25	146.86	144				1.75	
18-XI-72	0+284.73	33.75	180.61	144				1.75	
25-XI-72	0+312.90	28.17	208.78	120	24			1.75	
2-XII-72	0+340.65	27.75	236.53	136			8	2.00	
9-XII-72	0+348.15	7.50	244.03	40			104	2.00	Serious problems of creeping sands and increase of the filtrations into the face will make it necessary to install WELL POINTS in the face.
16-XII-72	0+359.40	11.25	255.28	60			84	2.00	
23-XII-72	0+369.15	9.75	265.03	52			92	2.00	Sands in the face with creeping water
30-XII-72	0+375.90	6.75	271.78	36			108	2.00	Holiday 12/24/72
6-I-73	0+386.40	10.50	282.28	56			88	2.00	Holiday 1/1/73
13-I-73	0+394.65	8.25	290.53	44			100	2.00	Strong thrusts are noted in the ground which deform the circle of voussoirs and which are stopped by injecting the zone.

SHAFT FACE 11 - SHAFT 13 OF THE CENTRAL INTERCEPT

Date	Chain	Advance m/wk	Cumulative advance m/wk	Effective excavation work time hours/wk	LOST TIME			Amount of water in the face (*)	OBSERVATIONS
					Breakdown in the shield (hr/wk)	Breakdown in the muck removal system (hr/wk)	Due to neither personnel nor equipment hr/wk		
20-I-73	0+402.90	8.25	298.78	44			100	2.00	Strong thrusts in the ground, cracking the voussoirs.
27-I-73	0+420.15	17.25	316.03	92			52	2.00	
3-II-73	0+432.15	12.00	328.03	72			72	2.00	Strong thrusts in the ground.
10-II-73	0+444.90	12.75	340.78	68			76	1.75	Holiday 2/5/73
17-II-73	0+462.15	17.25	358.03	96	12		36	1.75	
24-II-73	0+478.65	16.50	374.53	88			56	1.75	The thrusts begin to be minor.
3-III-73	0+492.90	14.25	388.78	80	30		34	1.75	
10-III-73	0+508.65	15.75	404.53	84			60	1.75	
17-III-73	0+528.15	19.50	424.03	104			40	1.75	
24-III-73	0+545.40	17.25	441.28	92			52	1.75	The shield of face 11-10 begins to operate so that from now on the same shaft services two faces.
31-III-73	0+570.46	25.06	466.34	132			12	1.50	
7-IV-73	0+605.71	35.25	501.59	144				1.50	
14-IV-73	0+633.46	27.75	529.34	120			24	1.50	
21-IV-73	0+646.96	13.50	542.84	72			72	1.50	Holidays 19, 20, 21/4/73
28-IV-73	0+669.46	22.50	565.34	120			24	1.50	
5-V-73	0+691.21	21.75	587.09	116			28	1.50	Holiday 5/1/73
12-V-73	0+716.71	25.50	612.59	136			8	1.50	
19-V-73	0+742.21	25.50	638.09	136			8	1.50	
26-V-73	0+768.46	26.25	664.34	140			4	1.50	Comparison of frame progress; 0 + 768.46= 0 + 770.25.

SHAFT FACE 11 - SHAFT 13 OF THE CENTRAL INTERCEPI

Date	Chain	Advance m/wk	Cumul-ative advance m/wk	Effective excavation work time (hr/wk)	LOST TIME			Amount of water in the face (*)	OBSERVATIONS
					Breakdown in the shield (hr/wk)	Break-down in the muck removal system (hr/wk)	Due to neither personnel nor equip-ment hr/wk		
2-VI-73	0+794.25	24.00	688.34	128			16	1.50	
9-VI-73	0+820.50	26.25	714.59	140			4	1.50	
16-VI-73	0+847.50	27.00	741.59	144				1.50	
23-VI-73	0+873.00	25.50	767.09	136			8	1.50	
30-VI-73	0+894.75	21.75	788.84	116			28	1.50	
7-VII-73	0+919.50	24.75	813.59	132			12	1.50	
14-VII-73	0+946.50	27.00	840.59	144				1.50	
21-VII-73	0+975.00	28.50	869.09	144				1.50	
28-VII-73	1+005.00	30.00	899.09	144				1.50	
4-VIII-73	1+032.75	27.75	926.84	140			4	1.50	
11-VIII-73	1+064.25	31.50	958.34	144				1.50	
18-VIII-73	1+089.00	24.75	983.09	120			24	1.50	
25-VIII-73	1+109.25	20.25	1003.34	104			40	2.00	
1-IX-73	1+113.00	3.75	1007.09	20			124	2.00	Introduction of large volume of water into the face 46 liters
8-IX-73	1+114.50	1.50	1008.59	36			108	2.00	Exploratory and drainage boreholes are made in the face.
15-IX-73	1+118.25	3.75	1012.34	20			124	2.00	
22-IX-73	1+126.50	8.25	1020.59	44			100	2.00	
29-IX-73	1+147.50	21.00	1041.59	112			32	2.00	
6-X-73	1+177.50	30.00	1071.59	140			4	1.75	
13-X-73	1+203.75	26.25	1097.84	132			12	1.75	
20-X-73	1+235.25	31.50	1129.34	144				1.75	
27-X-73	1+268.25	33.00	1162.34	144				1.75	
3-XI-73	1+304.25	36.00	1198.34	144				1.75	

SHAFT FACE 11 - SHAFT 13 OF THE CENTRAL INTERCEPT

Date	Chain	Advance m/wk	Cumulative advance m/wk	Effective excavation work time hours/wk	LOST TIME: Breakdown in the shield (hr/wk)	LOST TIME: Breakdown in the muck removal system (hr/wk)	LOST TIME: Due to neither personnel nor equipment hr/wk	Amount of water in the face (*)	OBSERVATIONS
10-XI-73	1+339.50	35.25	1233.59	144				1.75	
17-XI-73	1+372.50	33.00	1266.59	144				1.75	
24-XI-73	1_400.25	27.75	1294.34	144				1.75	Holiday 11/20/73
1º-XII-73	1+439.25	39.00	1333.34	144				1.75	
7-XII-73	1+460.72	21.47	1354.81	104			4	1.75	The tunnel is connected.

Appendix C

REFERENCES

1) S.G. Vick, A Probabilistic Approach to Geology in Hard-Rock Tunneling, M.I.T. School of Engineering Report R75-11, June 1974.

2) A. Sluz, A Probabilistic Approach to Soft Ground Tunneling, M.I.T. Thesis Submission, June 1975.

3) R.B. Peck, A.J. Hendron, Jr., and B. Mohraz, "State of the Art of Soft-Ground Tunneling," Proceedings of the North American Rapid Excavation and Tunneling Conference, Chicago, IL, June 5-7, 1972, p. 259-260.

4) L. Pietrzak and M. McJunkin, "Simulation as a Tunneling Research and Project Planning Tool," Proceedings of the North American Rapid Excavation and Tunneling Conference, San Francisco, California, June 1974, p. 176.

5) Ibid, p. 165.

6) R.W. Conway and A. Schultz, Jr., "The Manufacturing Progress Function," Journal of Industrial Engineering, Vol. X, January-February 1959, p. 39.

M. Gates and A. Scarpo, "Learning and Experience Curves," Journal of the Construction Division, ASCE, Vol. 58, March 1972, p. 79.

A. Vazsonyi, Scientific Programming in Business and Industry, J. Wiley, New York, N.Y. (1958) p. 382-395.

7) W.B. Hirschmann, "Profit from the Learning Curve," Harvard Business Review, Vol. 42, January-February 1964, p. 116.

8) M.T. Tayyabkhan and T.C. Richardson, "Monte Carlo Techniques," Chemical Eng. Progress Vol. 61, January 1965, p. 78.

G.L. Smith, "Monte Carlo Simulation — A Tool for Combating Uncertainty in Economic Analysis," presented at the 5th Annual Meeting, American Association of Cost Engineers, Philadelphia, PA, June 1966.

9) A.E. Hoerl, "Application of Ridge Analysis to Regression Problems," Chemical Eng. Progress, Vol. 58, March, 1962, p. 54.

D.W. Marquardt and R.D. Snee, "Ridge Regression in Practice," The American Statistician, Vol. 29, February, 1975, p. 3.

10. D.B. Hertz, "Risk Analysis in Capital Investment," Harvard Business Review, Vol. 42, January-February, 1964, p. 95.

Appendix D

REPORT OF INVENTIONS

No new inventions were developed during this study. Existing principles were applied to a problem in a new way, and a logic of problem-solution was developed.

370Copies

☆ U. S. GOVERNMENT PRINTING OFFICE: 1978--702-107--279

U. S. DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE, CAMBRIDGE, MA. 02142

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

U.S.MAIL

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF TRANSPORTATION
518